PROCEEDINGS

OF

THE ROYAL SOCIETY.

1849. No. 73.

March 1, 1849.

GEORGE RENNIE, Esq., Treasurer, Vice-President, in the Chair.

A paper was read, entitled "Minute Examination of the Organ of Taste in Man." By Augustus Waller, M.D. Communicated by Richard Owen, Esq., F.R.S.

The author commences by describing his mode of observation, which differs from that followed by previous observers. It consists in removing from the living tongue one of the papillæ, and immediately subjecting it to examination. He then proceeds to describe,—1st, the epithelium; 2nd, the fungiform papillæ; 3rd, the conical papillæ; and 4th, the inferior surface with its mucous glands, &c.

1. The epithelium is of two kinds; the flat plates with a central nucleus, which are mostly found clothing the stem and other regions of the fungiform papillæ; and the globular cells which compose most of the external parts of the processes of the conical papillæ.

2. The fungiform papillæ are found to consist of numerous small cones seated on a common stem. These secondary cones, already described by Albinus, are completely hidden by a common investment of epithelium which fills up the irregular spaces between them. Each of these cones contains capillary vessels, which, at the apex of the cone, either form a simple loop or a complex coil which is covered only by epithelian scales of the most attenuated nature. The author states that in these capillary vessels the motion of the blood may be observed for several seconds after the removal from the living body, and may be excited for a long time by the application of a slight degree of pressure. By these means he has been enabled to watch the passage of the red and white globules contained in the blood, and to detect in the human papillæ all the various phenomena in the transparent membranes of the lower animals. By allowing the blood to coagulate in the vessels, beautiful examples of injected papillæ may be obtained. The congestion of the vessels is much increased by compressing the point of the tongue before the removal of the

papillæ. The capillaries are connected together at the bases of the secondary papillæ, and arise from a common trunk immersed in the body of the papilla. The nerves are found to subdivide in the separate cones, in which they ascend to the apex and terminate in abrupt extremities, as in the frog, toad, &c. In the fœtus the fungiform papillæ are stated to consist of a simple cone without any secondary papillæ.

3. The conical or filiform papillæ of man are described to be of a compound nature, consisting of numerous secondary cones springing from a common stem. Each of these secondary cones is clothed with an elongated process which is fitted on the cone like a sheath. This process consists of elongated epithelial scales ascending towards the summit, and resembling in general appearance the feather of an arrow. At their summit these processes are clothed with an external zone of granular matter, which considerably adds to their thickness. This granular matter is often detached after the papilla has been removed a short time from the tongue. The blood-vessels form a simple loop at the summit of the papilla, and the nerves are arranged in a similar manner.

4. The inferior surface is described as very smooth, presenting numerous follicles abundantly supplied with blood-vessels and nerves. These follicles are generally of a conical shape and surrounded with an arch composed of epithelial cells. The nerves may frequently be detected and followed over the surface of the follicle, but their extremities are hidden amidst the blood-vessels.

The author has illustrated the paper by several drawings.

March 8, 1849.

The MARQUIS OF NORTHAMPTON, V.P., in the Chair.

A paper was read, entitled "Additional Observations on the Osteology of the Iguanodon and Hylæosaurus." By Gideon Algernon Mantell, Esq., LL.D., F.R.S., V.P.G.S., &c.

This memoir is supplementary to the author's former communications to the Royal Society on the same subject, and comprises an account of some important additions which he has lately made to our previous knowledge of the osteological structure of the colossal reptiles of the Wealden of the South-east of England.

The acquisition of some gigantic and well-preserved vertebræ and bones of the extremities from the Isle of Wight, and of other instructive specimens from Sussex and Surrey, induced the author to resume his examination of the detached parts of the skeletons of the Wealden reptiles in the British Museum, and in several private collections; and he states as the most important result of his investigations, the determination of the structure of the vertebral column, pectoral arch, and anterior extremities of the Iguanodon. In the laborious and difficult task of examining and comparing the numerous

detached, and for the most part mutilated bones of the spinal column, Dr. Mantell expresses his deep obligation to Dr. G. A. Melville, whose elaborate and accurate anatomical description of the vertebræ is appended to the memoir. The most interesting fossil remains are described in detail in the following order.

Lower Jaw.—Since the author's communication on the lower jaw of the Iguanodon, published in the Philosophical Transactions, part ii. 1848, he has discovered the right *angular* bone, which was previously unknown: from the circumstances under which this relic was found, he considers it probable that it belonged to the same individual as the teeth figured in Plate XVIII. of the Philosophical Transactions for 1848.

Vertebral column.—The vertebræ hitherto assigned to the Iguanodon consist of the middle and posterior dorsal and anterior caudal, as identified by means of the Maidstone specimen in the British Museum: the cervical, anterior dorsal, lumbar, and posterior and terminal caudals, were previously either undetermined or referred to other genera of saurians. The investigations of Dr. Melville have established the important and highly interesting fact, that the cervical and anterior dorsal vertebræ of the Iguanodon were convexo-concave—that is, convex in front and concave behind—as in the fossil reptile of Honfleur termed *Streptospondylus*, and in the existing pachyderms; the convexity gradually diminishing, and the anterior face of the body of the vertebra becoming flat, in the middle and posterior part of the dorsal region. The supposed Streptospondylian vertebræ of the Wealden (named *S. major* by Professor Owen in British Association Reports on fossil reptiles) are, in the opinion of the author and Dr. Melville, the true cervical vertebræ of the Iguanodon. The convexo-concave type of vertebræ was not confined to a single genus—the *Streptospondylus* of the Oolite—but prevailed in two, and probably in several, genera of extinct saurians of the secondary geological epochs; in like manner as the reverse form, the concavo-convex, predominates in the existing crocodilians and lizards.

Other large vertebræ found with ribs and bones of the extremities of the Iguanodon, and referred by Professor Owen to one or more species of Cetiosaurus, are regarded, in consequence of the peculiar structure of the neural arch, as belonging to the posterior dorsal and lumbar vertebræ of the former colossal reptile; and certain somewhat angular vertebræ, also previously assigned to a species of Cetiosaurus, are presumed to be the middle and distal caudals of the Iguanodon.

The Sacrum, of which portions of several examples belonging to individuals of much disparity in size have been obtained, is shown to consist of *six* anchylosed vertebræ; not of *five*, as described by Professor Owen; and the typical specimen in the possession of Mr. Saull, which the author figures and describes, is adduced in proof of the correctness of this opinion. The anterior vertebra, and the two posterior ones, are much larger and stronger than the three intermediate elements which occupy the centre of the arch of the sacrum.

Pectoral arch.—A perfect scapula discovered in the strata of Tilgate Forest, and which corresponds with the coracoid bone, provisionally assigned to the Iguanodon in the memoir of 1841 (Phil. Trans. Pl. IX. fig. 11), Dr. Mantell has been enabled to refer to that reptile, by the fortunate interpretation of portions of two scapulæ which are preserved in the Maidstone specimen, but had not previously been recognized as such. As the clavicles were long since determined, the essential elements of the pectoral arch are now ascertained, and the author gives a restored outline of this important part of the skeleton, based upon these data.

Humerus.—A humerus three feet long, discovered by Mr. Fowlestone in the Isle of Wight, has been ascertained by the author to belong to the Iguanodon, from the presence of a small but corresponding bone in the Maidstone fossil. This bone, from its disproportionate size in comparison with the femur with which it is collocated—being one-third shorter—was formerly assigned by Dr. Mantell to the fore-arm; but the large humerus from the Isle of Wight, which, except in magnitude, is identical with that from Maidstone, leaves no doubt upon the subject. It is now therefore, for the first time, ascertained, that in the Iguanodon, as in many fossil and recent reptiles, the anterior extremities were much shorter and less bulky than the posterior. The radius and ulna are still undetermined, but the author states that there are some imperfect bones in his former collection, now in the British Museum, which he thinks will be found to belong to the fore-arm.

Hinder extremities.—The colossal magnitude of the Iguanodon is strikingly shown by some femora- and leg-bones recently discovered. One *femur* is 27 inches in circumference, and must have been 4 feet 8 or 10 inches in length; and a tibia, found with the same, is 4 feet long.

Dermal scutes and spines.—The author figures and describes several dermal scutes and spines, and states that a microscopical examination of the large angular bones of the Hylæosaurus (Phil. Trans. 1841, Pl. X. fig. 1), supposed by him to be ossified dermal spines, but which Professor Owen regarded as the abdominal extremities of ribs, proves the correctness of his own opinion; their structure being identical with that of the acknowledged dermal scutes.

In the summary which concludes the memoir, Dr. Mantell states that the facts described confirm in every important point the physiological inferences relating to the structure and habits of the Iguanodon and Hylæosaurus, enunciated in his former communications; and thus, after the lapse of a quarter of a century, he concludes his attempts to restore the skeletons of the colossal saurian herbivores, of whose former existence a few water-worn teeth and fragments of bones were the only indications, when, in 1825, he first had the honour to submit to the Royal Society a notice on the teeth of the Iguanodon.

March 15, 1849.

The MARQUIS OF NORTHAMPTON, V.P., in the Chair.

A paper was read, entitled "Researches in Physical Geology." Part II. By Henry Hennessy, Esq. Communicated by Major Beamish, F.R.S.

In this communication the author states that, having in Part I. (read to the Society in December 1846) endeavoured, by generalizing the hypothesis on which is usually founded the theory of the earth's figure, not only to improve that theory, but also to establish a secure basis for researches into the changes which may have taken place, within and at the surface of the earth, during the epochs of its geological history, his object here is to discover relations between the interior structure of the earth and phenomena observed at its surface, and also the effects of the reaction of the fluid nucleus, described in Part I., upon the solid crust. This memoir is divided into sections, each containing a distinct investigation; and the statement of the geological results is given at the end.

I. *The Pressures of the Shell and Nucleus at their surface of contact.*

In the investigation of these pressures the earth is supposed to consist of a nucleus of fluid matter inclosed in a solid shell, the inner and outer surfaces of which are spheroidal, but nearly spherical; and both shell and nucleus are supposed to consist of strata varying in density according to some unknown inverse law of the radii. The pressure at the inner surface of the shell is conceived to be due to a constant pressure, which is the same for every point, and a variable pressure, arising from the difference in form of the surface of the nucleus and inner surface of the shell. On these suppositions, simple expressions for the pressure on any stratum of the nucleus and on the shell's inner surface are deduced.

II. *The Variation of Gravity at the earth's surface.*

The author does not assume in this investigation that the laws of arrangement of the particles composing the shell and the nucleus are necessarily the same; so that the expression which he obtains for gravity at any point on the earth's surface, besides being a function of the latitude of that point, and of the radii and ellipticities of the shell's inner and outer surfaces, contains functions depending on the constitution of the shell and nucleus. He states that this expression for gravity is not merely speculative, but that it will be found to assist in explaining certain apparent anomalies detected by observation in the variation of gravity at the earth's surface, as well as in pointing out the limits assigned by observation to the thickness of the crust.

III. *The Laws of Density of the Shell and Nucleus.*

According to the author's views in a subsequent section, it appears that the solidification of the earth could not proceed simulta-

neously from the centre towards the surface, and from the surface towards the centre. He therefore, in determining the laws of density of the shell and the nucleus, restricts his investigations to the latter case, in which the solidification proceeds from the surface towards the centre.

IV. *The Forms of the Strata of the Shell.*

The author conceives a surface to exist which may be called the effective surface of separation of the perfect fluid of the nucleus and the imperfectly fluid portion adhering to the shell, the form of which surface will depend on the pressures which the fluid exerts. As it may be shown that the pressure of the perfect fluid will not be constant, the surface of separation will tend to assume a form different from that of the inner surface of the shell. If we admit that the matter composing the nucleus becomes denser in assuming the solid state, the author concludes that the inner surface of each stratum added to the shell will be more oblate than its outer surface; and that thus the tendency will always be to render the inner surface of the shell more and more oblate. He then deduces an expression for the ellipticity of the fluid surface.

V. *The principal Moments of Inertia of the Earth.*

From his investigations the author concludes that, as the thickness of the shell increases, the difference between the greatest and the least moment of inertia of the earth also increases; which conclusion is independent of any knowledge of the absolute laws of density of the earth's interior.

VI. *On the existence of a Solid Nucleus within the Earth.*

The conclusion arrived at here is, that if a solid nucleus existed, as the pressure on it would be continually diminishing, while its temperature would remain nearly constant, this nucleus, instead of increasing in magnitude, would tend to return to its original fluid state.

VII. *The directions of the Fissures in the Shell which might be produced by the action of the pressures in Section* I.

The author states that the tendency of the variable pressure is in the first instance to produce fissures parallel to the equator; that when such a fissure was once commenced the tendency would be to propagate it along a parallel of latitude, until the force of the tensions became sufficiently lessened by the separation of the extended portion of the shell; and that similar fissures would be formed simultaneously and symmetrically on each side of the equator. Subsequently, as may readily be deduced from Mr. Hopkins's investigations, the tendency will be to form fissures at right angles to those previously existing. If, however, the constant pressure were far greater than the variable, the directions of the fissures would be governed chiefly by accidental causes; but if a fissure commenced, it

would continue to be propagated in the great circle coinciding with its first direction, unless accidental causes should alter its course.

VIII. *On the existence of a Zone of least disturbance in the Shell.*

The author investigates analytically the position of this zone, and from the results of his investigation, points out the conditions under which it will exist, and also the consequences that will follow from its non-existence.

IX. This section is devoted to the calculation of some of the constants contained in the formulæ of the preceding sections.

The following are the geological deductions from the foregoing investigations:—

1. The stability of the axis of rotation of the earth will progressively increase during the process of solidification.

2. By employing the values of the constants obtained in Section IX., it appears that the thickness of the earth's crust cannot be less than 18 miles, and cannot exceed 600 miles.

3. The earth's primitive ellipticity, when entirely fluid, was less than its present ellipticity; but their difference may be neglected.

4. If a zone of least disturbance existed near the parallel of mean pressure, the directions of great lines of elevation should be in general parallel, or perpendicular to the equator. Its non-existence there, which observation seems to show, proves at least that the variable pressure did not predominate over the constant. Since, as yet, observation goes to prove that such a zone does not exist on the earth's surface, we must provisionally conclude that the constant pressure greatly predominated over the variable, and, consequently, that the directions of the lines of elevation must be comparatively arbitrary.

5. That great friction and pressure exist at the surface of contact of the nucleus and shell, is shown from the conclusions arrived at in Section IV., combined with the important result obtained by Mr. Hopkins in his second memoir on Physical Geology (Phil. Trans. 1840, p. 207).

6. The amount of elastic gases given off from the surface of the nucleus rapidly decreases as the thickness of the shell increases.

7. The expression obtained for the variation of gravity shows that, if the angular velocity of rotation of the earth remained unchanged, the waters on its surface would tend to accumulate towards the equator, for the increase of gravity, in going from the equator to the poles, would be less according as the shell's thickness increased.

March 22, 1849.

The Very Rev. The DEAN OF WESTMINSTER, Vice-President, in the Chair.

A paper was read, entitled "An Account of the Aurora Borealis

of the 17th of November 1848." By the Rev. Charles F. Watkins. Communicated by the Marquis of Northampton, V.P.R.S.

The author states that, "About half-past 7 P.M. the sky assumed the appearance which it usually does immediately preceding the action of what are called the Northern Lights. In the northern half it was quite clear for about forty-five degrees from the meridian, of a pale blue, and covered with a faint light, such as generally ushers in the moon at her rising. Towards the east and west this light gradually diminished, and south of those cardinal points the dimness as gradually thickened.

"Soon after eight the coruscations began by the usual lambent strokes of a shining filmy matter, like the sudden shooting forth and instantaneous retroceding of a serpent's tongue. They commenced in the north-east, and shot upwards in an angle of about 70 degrees of inclination towards the south, and to about 60 degrees in length, more or less, leaving the sky clear to the north, and in a manner gradually chasing the clouds, upon whose receding bounds they glanced further to the south.

"In a short time the same kind of electrical action commenced in the north-west quarter of the heavens, and continued simultaneously with that from the north-east, both increasing in rapidity, intensity and depth of colour; till at length an entire hemispherical arch of crimson and purple, but with uneven edges, spanned the heavens from east to west, and remained suspended there for several minutes. By degrees this arch broke up into separate masses of highly and parti-coloured clouds, resembling those which are seen floating about after the setting of an ardent sun. Meanwhile the lighter coruscations continued,—now glancing upwards on the northern edges of the clouds, which were still slowly receding to the south, and now shooting up beneath them as they steadily retreated. At the same time others of a redder hue played now alternately, and now in union with them.

"About a quarter past nine an extraordinary phenomenon occurred, such as I never before witnessed; the zenith assumed the appearance of a crimson coronary apex to distinct but connected bands of various shades of crimson, green and purple, in which the crimson prevailed, flowing down from thence like a canopy, encircling the upper portion of the heavens, which to me presented the inside view of a ribbed and vaulted cupola. By degrees this beautiful creation dissolved, and the body of clouds, against which the electrical forces seemed to have been in hostile pursuit, fled away to the south; the elementary action ceased: a silent calm returned, and nothing but the tranquil light, still shining in the north, remained to indicate the recent scene. The wind had blown with a fresh but steady breeze from the north-west, during the continuance of the phenomenon.

"Without entering at present into any disquisition upon the causes, I will now state the meteorological results which I immediately anticipated and have seen to follow these atmospheric phenomena.

"I have observed, and have stated my observations for some years

past, that the certain result of all meteoric coruscations and iridescences in the sky, is a fall of rain, snow or hail,—on this general principle, that the condensation of the crystalline particles of floating vapours which ensues upon electrical action, must be followed by precipitation; and these coruscations and iridescences are both the reflected evidences of such condensation of crystalline matter, and therefore the harbingers of such precipitation. It is the case with solar and lunar rainbows, falling stars, mock-suns, halos, lightning, aurora, and that undefined pearly lustre which sometimes appears in the neighbourhood of the sun.

"Accordingly, on the following morning, Saturday the 18th, I found the barometer had sunk considerably, and the wind had veered round from north-west to south-west, against the course of the sun, both in general, and especially when united, the forerunners of rain. Accordingly at 2 o'clock P.M. a smart shower came on in Northampton, but was of short duration. At 9 P.M. a heavier shower was experienced at Brixworth; and in the course of the night, but I cannot say at what hour, I was awakened to a still heavier shower; but the quantity of rain that had fallen did not seem to have affected the ground much on the following morning, and therefore I conclude that it was not great.

"Sunday the 19th was fine and bright; the wind went up to the westward, and the barometer rose rapidly—a general indication of an early change. Towards morning of Monday the 20th, another shower fell, and the wind went back to the south-west with a falling barometer. In such cases I generally find that rain ensues about midday, or at least when the wind and sun meet in the south-west. But on this occasion it continued blowing strong all the day, and for some time in the night with increased violence. But at last the wind fell, and was succeeded for awhile by heavy rain, thus verifying my anticipations on this particular occasion, and the general theory which I have discussed."

March 29, 1849.

GEORGE RENNIE, Esq., Treasurer, Vice-President, in the Chair.

The following papers were read:—

1. "Examination of the Proximate Principles of some of the Lichens."—Part II. By John Stenhouse, Esq., F.R.S.

Gyrophora pustulata.

The author states that this lichen, which is the "Tripe de Roche" of the Canadian hunters, has been long employed by the manufacturers of archil, though the quantity of colouring matter contained in it is by no means considerable, being little more than a twelfth of that in the *Roccella Montagnei*. The *Gyrophora pustulata*, on which the author operated, was brought from Norway, where it is

annually collected in considerable quantity for the manufacture of archil. The colouring principle was extracted by maceration with milk of lime, and was precipitated in a gelatinous state by neutralizing the lime solution by muriatic acid, precisely in the way so frequently described in the author's former paper (Phil. Trans. 1848). The precipitate was gently dried, and then dissolved in hot spirits of wine. On the cooling of the liquid, the colouring principle was deposited in small soft crystals, which by digestion with animal charcoal and repeated crystallizations were rendered quite colourless. This principle, to which the author has given the name of *Gyrophoric acid*, is almost insoluble in either hot or cold water, and is also much less soluble in hot spirits of wine than either orsellic, erythric, or any of the analogous colouring principles. It is neutral to test-paper, and possesses no saturating power, as the smallest quantity of an alkali gives its solutions an alkaline reaction. Gyrophoric acid strikes a bright red fugitive colour with hypochlorite of lime; and when macerated with a solution of ammonia, it is slowly converted into a purplish-red colouring matter, similar to that yielded by the analogous acids under the same circumstances. When subjected to analysis, the formula of gyrophoric acid was found to be $C_{36}\,H_{18}\,O_{15}$.

Gyrophoric acid when boiled for some hours in alcohol yields an ether similar in appearance and properties to the erythric and lecanoric ethers; its formula is $C_4\,H_5\,O + C_{36}\,H_{18}\,O_{15}$.

Gyrophoric acid unites with the alkalies and metallic oxides, but the compounds which it forms possess little stability and cannot be procured of an uniform composition.

Lecanora tartarea.

This lichen, like the *Gyrophora pustulata*, has been employed from an early period in the manufacture of archil. It is found in considerable abundance in the hilly districts of the northern parts both of Scotland and Ireland. The lichen on which the author operated came from Norway. He found it also to contain gyrophoric acid, in much about the same quantity as the *Gyrophora pustulata*. This fact was established by the analysis of the acid itself and of its ether compound.

Brom-orcine.

In the author's former paper on the proximate principles of the lichens, read before the Royal Society on the 3rd of February 1848, he described a crystalline body obtained by cautiously adding bromine to an aqueous solution of orcine. In this second part he states that, in the 'Comptes Rendus' for August of the same year, Messrs. Laurent and Gerhardt describe the very same compound obtained in precisely the same way, without even hinting that it had been previously discovered. These gentlemen however give a different formula for the compound, viz. $C_{14}\,H_5\,Br_3\,O_4$, or orcine in which three equivalents of hydrogen are replaced by three equivalents of bromine; and the author is disposed to adopt this formula,

as, on repeating the analysis of the compound, he found that he had somewhat over-estimated the amount of bromine contained in it, while its other constituents were determined correctly enough.

Beta-orcine.

This substance, described by the author in the Philosophical Magazine for July 1848, may be obtained from usnic acid, either by destructively distilling it, or by acting on it with alkalies.

Beta-orcine crystallizes very beautifully in four-sided prisms surmounted at either end by four-sided pyramids. These crystals have a brilliant lustre, and are from three quarters of an inch to an inch long. Their solution strikes a fugitive bright-red colour with hypochlorite of lime, and with a solution of ammonia it yields a permanent blood-red colouring matter which becomes darker on standing. The formula of beta-orcine, which however is merely empirical, is $C_{16} H_{10} O_4$.

Quintonitrated erythromannite.

In his former paper on the lichens, the author has described, under the name of *pseudo-orcine*, a remarkably beautiful crystalline body which is obtained by boiling either picro-erythrine, or erythric acid, with an excess of lime or baryta. This substance he then regarded as very analogous to mannite both in its composition and properties, and this view having been amply verified by an experiment which he has recently made, he has been induced to change the name of this compound to *erythro-mannite*, as at once indicating its origin and its most striking properties. After referring to the discovery by Messrs. Flores Domonte and Menard, of "Mannite quintonitrique" or mannite in which five equivalents of water are replaced by five equivalents of nitric acid, and which possesses the remarkable property of detonating so violently when struck by a hammer that M. Sobrero has proposed employing it, instead of fulminate of mercury, in the manufacture of percussion-caps, the author states that when erythro-mannite is treated with fuming nitric acid, in exactly the same way as mannite, it yields a perfectly analogous compound, or erythro-mannite in which five equivalents of water are replaced by five equivalents of nitric acid. This compound, which he has called *quintonitrated erythromannite*, is also insoluble in water, but crystallizes out of hot spirits in large flat crystals resembling those of benzoic acid, only larger and exhibiting a much more pearly lustre. Quintonitrated erythromannite also detonates with great violence when it is mixed with a little dry sand, and is strongly struck with a hammer.

In order to exhibit more distinctly the close analogy which subsists between the four compounds, their rational formulæ are given, viz.

Mannite ..... $= C_{12} H_{14} O_{12}$;
Erythro-mannite ..... $= C_{11} H_{14} O_{11}$;
Quintonitrated mannite ..... $= C_{12} H_9 O_7 + 5NO_5$;
Quintonitrated erythromannite $= C_{11} H_9 O_6 + 5NO_5$.

2. "General Methods in Analysis, for the resolution of Linear Equations in Finite Differences and Linear Differential Equations." By Charles James Hargreave, Esq., LL.B., F.R.S. &c.

The investigations presented in this paper consist of two parts; the first offers a solution, in a qualified sense, of the general linear equation in finite differences; and the second gives an analysis of the general linear differential equation with rational factors, so far as concerns its solution in series.

The author observes that there does not at present exist any general method of solving linear equations in finite differences of an order higher than the first; and that with reference to such equations of the first order, we obtain insufficient forms which are intelligible only when the independent variable is an integer. It is in this qualified sense that the solutions proposed in this paper are to be taken; so that the first part of these investigations may be considered as an extension of this form of solution from the general equation of the first order to the general equation of the nth order.

In the second part, the author points out a method by which the results of the process above indicated may be made to give solutions of those forms of linear differential equations whose factors do not contain irrational or transcendental functions of the independent variable, or contain them only in an expanded form.

This object is effected by means of the theorem, relative to the interchange of the symbols of operation and of quantity, propounded by the author in a former memoir published in the Philosophical Transactions (Part I. for 1848, p. 31). It is one of the properties of this singular analytical process that it instantaneously converts a linear equation in finite differences into a linear differential equation; so that whenever the former is soluble, the latter is soluble also, provided the result be interpretable; a condition satisfied when the functions employed are rational algebraical functions.

Notwithstanding the qualified character of the solutions previously obtained for linear equations in finite differences, the solutions obtained from them by this process are free from all restriction. The solutions in series can be written down at once from the equation itself, inasmuch as each series has its own independent scale or law of relation; and no difficulties arise from the appearance of equal or imaginary roots in the equation determining the incipient terms of the series. These circumstances do indeed cause a certain variation of form; but they do not compel us to resort to any special process in each individual case.

The perfect separation and independence of the scales, or laws of relation of the series enables the author to discuss the characters of the series with reference to their convergency or divergency, and to classify these equations into sets having peculiar and distinguishing properties in regard to this subject.

The first set includes those equations whose solutions can always be found in *convergent* series of *ascending* powers of the independent variable; and if in such case the equation be solved in series of *descending* powers (which can be done by this process), those series are certainly always *divergent*.

The distinguishing marks of this class of equations are,—that the factor of the highest differential coefficient contains one term only; and that (the terms being arranged in an ascending order) when this term is x^p, the factor of the next differential coefficient must not contain a term lower than x^{p-1}, the next not lower than x^{p-2}, and so on to the end.

The second set includes those equations whose solutions can always be found in *convergent* series of *descending* powers of the independent variable; and if in such case the equation be solved in series of *ascending* powers, they are always *divergent.*

The distinguishing marks of this class of equations are,—that the factor of the highest differential coefficient contains one term only; and that when this term is x^p, the next factor must stop at x^{p-1}, the next at x^{p-2}, and so on to the end.

The third set includes equations whose solutions can be found in series of *ascending* powers which for some values of the independent variable are *convergent,* and for other values *divergent*; and whose solutions can also be found in series of *descending* powers which are *divergent* for all values for which the other series are *convergent,* and *convergent* for all values for which the other series are *divergent.*

The distinguishing marks of this class of equations are,—that the factor of the highest differential coefficient contains two terms only, and that with reference to the first of such terms the equation is under the restriction mentioned with regard to the first set, and that with reference to the second of such terms it is under the restriction mentioned with regard to the second set.

The fourth set includes equations whose solutions are or may be *divergent* for some values of x, both in the ascending and descending series. In some cases, the ascending series is necessarily divergent, and the descending series convergent or divergent according to the value of x; in other cases, the descending series is necessarily divergent, and the ascending series convergent or divergent according to value; and in the remaining cases, both series are convergent or divergent according to value, but not so as to be necessarily complementary to each other in this respect.

The distinguishing marks of this class are,—that the first factor may contain more than two terms; and that *either* the restriction of the first set is transgressed with reference to the highest term, *or* the restriction of the second set is transgressed with reference to the lowest term. In this set the divergency arising from value is of a finite character; and, as the series approach without limit to ordinary recurring series, there is a probability that the passage from convergency to divergency is not attended with danger.

The fifth set includes equations whose solutions, whether in ascending or descending series, are always *necessarily divergent.*

The distinguishing mark of this class is, that it transgresses *both* the restrictions to one or other of which the last set is subjected. In this case the divergency is infinite, and appears to be of an unmanageable character.

The analogy of the process leads to a presumption, that in all

cases of divergency, above referred to, the corresponding convergent solutions are in series infinite in both the ascending and descending directions.

The author observes in conclusion, that the inverse calculus of the process here developed may be employed for the discovery of the generating functions of series whose laws of relation are given.

The Society then adjourned over the Easter holidays to meet again on the 19th of April.

April 19, 1849.

The EARL OF ROSSE, President, in the Chair.

A paper was read, entitled "On the Meteorology of the Lake District of Cumberland and Westmoreland." By John Fletcher Miller, Esq. Communicated by Lt.-Colonel Sabine, R.A., For. Sec. R.S., &c.

This paper contains the results of meteorological observations made during 1848, similar to those made in the same district in preceding years, which were last year communicated to the Society. On these results, the author remarks that the fall of rain in the lake district, during the year 1848, greatly exceeds the amount in any other year since the register was commenced in 1844; and that there is a similar excess with reference to the number of wet days. The total depth of rain, in 1848, at Seathwaite, the wettest station, was 160·89 inches; and of this quantity, 114·32 inches fell in the six months, February, July, August, October, November and December. In February there fell the unprecedented quantity 30·55 inches.

The mountains flanking the lake-district valleys increase in altitude with great regularity towards the head or eastern extremity of the vale, and it appears that it is there that the greatest depth of rain is invariably found. The amount increases rapidly as the stations recede from the sea, and towards the head of the valley the incremental ratio is exceedingly great. At Loweswater, Buttermere and Gatesgarth, about two miles apart in the same line of valley, the depths of rain were respectively 76 inches, 98 inches and 133·5 inches.

From the observations of the thermometer, the author concludes that the climate in the mountain valleys in this district is milder and more equable, not only than in the open country in their immediate vicinity, but also than in that considerably to the south. This he attributes to the lakes giving out during the winter the heat absorbed by them in the summer, and to the radiation from the rocky mountain breasts in the valleys, but principally to the heat evolved in a sensible form by the condensation of enormous volumes of vapour.

Last summer a pair of Rutherford's self-registering thermometers

were stationed by the author on the summit of Sca-Fell Pike. He states that from the maximum thermometer no correct readings could be obtained; but that the minimum gave the following:—July, 22°; August, 24°; September, 18°; October, −6°; November, −6°; December, −9°. It appears that on the night between the 2nd and 3rd of January the minimum thermometer indicated the extraordinary low temperature −34° Fahr.: at the same date a naked thermometer on grass at Whitehaven fell to +4°, and one on raw wool to −2°·8.

The author states that the results obtained from the mountain gauges during the last year, are in strict accordance with those of the two preceding years, and thus confirm the correctness of the conclusion drawn from them in his former paper, "that the quantity of rain increases from the valley upwards to an altitude of about 2000 feet, above which it begins to diminish." He does not, however, by any means infer that the law which appears to regulate the distribution of rain in the mountain district of Cumberland will equally apply to every similar locality.

April 26, 1849.

The EARL OF ROSSE, President, in the Chair.

A paper was read, entitled "A Report upon further Observations of the Tides of the English Channel made by order of the Lords Commissioners of the Admiralty in 1848, with remarks upon the Laws by which the Tidal Streams of the English Channel and German Ocean appear to be governed." By Captain F. W. Beechey, R.N., F.R.S. Communicated by the Lords Commissioners of the Admiralty.

The author commences this report by observing, that the result of the observations upon the tides in the English Channel, made in the course of the summer of 1848, had confirmed in a satisfactory manner the view he had taken of the tidal phenomena of the channel, in the report communicated to the Royal Society last year, and printed in the Philosophical Transactions (Part I. 1848), namely, that there is a meeting and a separation of the streams between Alderney and the Start: that the whole space between the Start and Scilly is under the joint influence of the channel and offing streams: that from the vicinity of the Start to the vicinity of Hastings the stream runs true up and down the channel; and moreover that this stream throughout turns nearly simultaneously with the time of high and low water on the shore at the virtual head of the tide, which he places in the vicinity of Dover; and lastly, that the streams which meet off the Start are turned down into the Gulf of St. Malo, and *vice versâ*.

He then takes a comprehensive view of the tidal system of the English Channel and German Ocean together, and considering them as one great canal open at both extremities to the free admission of a great tidal wave, which might be supposed to meet and form a combined or stationary wave (art. 187, Encyclopedia Metropolitana), he infers that in such a case, there ought to be in the *eastern half* of such a canal, a recurrence of the phenomena which had been found to exist in the *western half*. He proceeds to explain that, from a valuable series of observations in the German Ocean by Captain Washington, R.N., and other authorities, it does appear that, inverting the direction of the stream, there is a correspondence of phenomena in almost every respect: that the offing and channel streams meet off Lynn, as off the Gulf of St. Malo, at the same hours, and at the same distance nearly from the virtual head of the tide: that the phase of the tide at Lynn corresponds with the phase of the tide at Jersey: that there is an increased rise there also; and that from the meeting of the tides off Lynn to the meeting of the streams off Dover, there is, as in the former case, a stream which turns nearly simultaneously with the high and low water on the shore at Dover; the incoming and outgoing streams coinciding with the rising and falling water there; and that there is, in fact, a complete identity of tidal phenomena in both parts of the supposed canal; of this an illustration is given in two plans.

The author states that the meeting of the waves which enter the canal at opposite points does not occasion a stationary point of permanent slack-water, but one wave alternately prevails, so that the point of slack-water oscillates between Ramsgate and Hastings nearly, and occasions an inversion of the stream at about two hours before that of the true stream of the channel. He thinks it convenient for the purposes of navigation to consider this an *intermediate* stream, although in reality it is only a shifting of the place of the meeting and divergence of the opposite channel streams. To illustrate this part of the paper a table is given, in which the courses of the streams in various compartments of the supposed canal are given at every hour of the tide.

The author thinks this system of tides sufficiently established for the purposes of navigation, but with regard to the perfectly simultaneous motion of the stream throughout the stationary wave, he is of opinion that nothing but simultaneous observations will be considered satisfactory to science upon such a point, and these he hopes will be supplied by the observations of the ensuing summer.

The advantage of referring the motion of the stream to a standard such as that of the Dover tide-table will, it appears, be sensibly felt by the mariner, who will now have his course through the moving waters of the channel rendered simple and plain, instead of being perplexed with unsatisfactory references, and with calculations which in too many instances, it is believed, have caused the set of the tide to be wholly disregarded.

The want of a standard to which desultory observations, made in

various parts of the channel, could be referred, the author believes to have been the occasion of several erroneous impressions of a tendency somewhat dangerous to navigation. As such he considers the following:—that the tide in all parts of the channel partakes of a rotatory motion and is never at rest, and that a ship's reckoning will never be far out in consequence, as she will never be carried far in one direction: that a vessel arriving off the Start at low water could, by sailing seven or eight knots an hour, carry ten or eleven hours' favourable tide to Beachy Head: that in the German Ocean the stream sets north-east on one side, whilst it is running south-west on the other: that there is a tide and half-tide in the channel, so that when the stream has done in shore, by standing out, a ship will carry the stream three hours longer, or nine hours in one direction: and lastly, that the stream runs strongest at high and low water throughout the channel, and is motionless at half-tide.

These impressions do not appear to be justified by the observations. The stream, when not diverted by rivers or estuaries, appears to run true up and down the channel, and from side to side nearly; between the Start and Hastings, in the English Channel, scarcely varying a point for nearly five hours; and in the German Ocean for about four hours; the varying of the stream there being due, in the author's opinion, to the influence of the Thames and the rivers of Holland. As the stream turns nearly with the high and low water on the shore at Dover, there cannot be nine hours' current in one direction. With regard to the time at which the stream attains its greatest strength, he states that all the observations agree in fixing it at about half-tide (Dover).

The erroneous impressions above mentioned, the author considers have arisen from the times of the observations when made having been referred to the times of high water at places differing *two or three hours from* the time of high water at the *head of the wave*, or from an early popular opinion that the turn of the stream in the offing coincides with the rise and fall of the water on the shore.

The paper concludes with some remarks on the forms of the tide-wave between Cromarty and the Land's End, which are exhibited in two plans at every hour of the tide, obtained from a combination of the ranges and establishments of Dr. Whewell with those of M. Chazallon; and attention is particularly drawn to the relative lengths of the *stationary wave* and the *waves* by which *it is generated*; the *former* wave being only *half the dimensions of the latter*. These forms are exhibited on a reduced scale, but much exaggerated in height, and afford a comparison between the curve assumed by the stationary wave and that which the waves would have assumed had they rolled on in an uninterrupted course.

His Grace the Lord Archbishop of Canterbury, and the Right Honourable Lord John Russell, were admitted into the Society on January 25, 1849.

May 3, 1849.

The EARL OF ROSSE, President, in the Chair.

In accordance with the Statutes the President read the following list of Candidates recommended by the Council for election into the Society:—

John Couch Adams, Esq.
Thomas Andrews, M.D.
Robert Alfred Cloyne Austen, Esq.
Charles Barry, Esq.
Benjamin Collins Brodie, Esq.
John Dalrymple, Esq.
James Glaisher, Esq.
Sir Robert Kane, M.D.
William Lassell, Esq.
Henry Beaumont Leeson, M.D.
Andrew Crombie Ramsay, Esq.
John Scott Russell, Esq.
Francis Sibson, M.D.
Robert Stephenson, Esq.
Lieut.-Col. Philip Yorke.

A paper was read, entitled "On the Reduction of the Thermometrical Observations made at the Apartments of the Royal Society from the year 1774 to 1781, and from the year 1787 to 1843." By James Glaisher, Esq. of the Royal Observatory, Greenwich. Communicated by John Lee, Esq., LL.D., F.R.S. &c.

In this paper, the author states that he has examined all the thermometrical observations which have been made at the Apartments of the Royal Society, with the view of ascertaining whether the diurnal variations at different epochs were in accordance with those which he had determined from the Greenwich observations, and which are contained in his paper published in the Philosophical Transactions for 1848. The result of this investigation was, that the corrections contained in the tables in his former paper were applicable to the observations of all the years since 1774.

The author is led from these examinations to the conclusion,—1st, that the instruments used have been uniformly good; 2ndly, that the observations have been faithfully recorded as read from the instruments; 3rdly, that the readings have been taken with great care with respect to the times stated; and lastly, that the observations were well-worth the necessary labour of reduction. He finds, however, that some of the more recent observations of the self-registering instruments are liable to some uncertainty.

Having satisfied himself that the observations were well-worth any amount of labour that might be bestowed on them, the author was anxious to reduce them to a useful form, but, in consequence of the great amount of work that would be required for the reduction of so extensive a series, he for some time hesitated to enter upon this labour. Finding however that there was a demand for the results of trustworthy observations extending backwards many years, and having, besides, the hope of connecting the Greenwich series of observations with these, he determined to perform the work. He states that the mean temperature of every month was determined in the first instance from the observations which had been made during the day, and secondly, from the observations of the self-registering

instruments. Tables are appended to the paper, showing the monthly, quarterly and yearly mean temperatures, with those of groups of years, and other tables exhibiting the departure of every individual result from the mean of all.

The author concludes by stating, that hitherto the mean temperature at Somerset House has been estimated a great deal too high. He does not here enter into the investigation as to whether the temperature as now determined is too high for the geographical position and elevation of Somerset House, but proposes to do so, in a paper he is preparing with the view of connecting the Somerset House with the Greenwich series, and of bringing up all the results to the present time. He hopes also, at some future time, to present results from the barometrical observations arranged in a similar manner.

May 10, 1849.

The EARL OF ROSSE, President, in the Chair.

The following communication was read:—"Remarks on M. De la Rive's Theory for the Physical Explanation of the Causes which produce the Diurnal Variation of the Magnetic Declination," in a letter to S. Hunter Christie, Esq., Sec. R.S., from Lieut.-Col. Sabine, For. Sec.R.S. Communicated by S. Hunter Christie, Esq.

My dear Sir, Woolwich, April 16, 1849.

The *Annales de Chimie et de Physique* for March last contains a letter from M. De la Rive to M. Arago, in which a theory is proposed, professing to explain on physical principles the general phenomena of the diurnal variation of the magnetic declination, and, in particular, the phenomena observed at St. Helena and at the Cape of Good Hope, described in a paper communicated by me to the Royal Society in 1847, and which has been honoured with a place in the Philosophical Transactions.

Although I doubt not that the inadequacy of the theory proposed by M. De la Rive for the solution of this interesting problem will be at once recognised by those who have carefully studied the facts which have become known to us by means of the exact methods of investigation adopted in the magnetic observatories of recent establishment, yet there is danger that the names of De la Rive and Arago, held in high and deserved estimation as authorities on such subjects, attached to a theory, which moreover claims reception on the ground of its accordance with "well-ascertained facts" and "with principles of physics positively established," may operate prejudicially in checking the inquiries which may be in progress in other quarters into the causes which really occasion the phenomena in question; I have thought it desirable therefore to point out, in a very brief communication, some of the important particulars in which M. De la Rive's theory fails to represent correctly the facts which it

professes to explain, and others which appear to me to be altogether at variance with, and opposed to it.

1. M. De la Rive's theory, in a few words, is as follows:—

In consequence of the inequalities of temperature in the higher and lower strata of the atmosphere, electric currents are generated, which in the higher regions proceed from the equator to the poles, and return at the surface of the earth from the poles to the equator; the return current causing in the northern hemisphere the north end of the magnet to deviate in the one direction, and in the southern hemisphere in the opposite direction; the deviation being at any given place greatest at the hour (about $1^h{\cdot}30$ P.M.) when the difference of temperature in the upper and lower strata of the atmosphere is greatest, and of course increasing until that hour, and subsequently diminishing.

That the north end of the magnet does thus deviate in the forenoon towards the west in the northern hemisphere, and towards the east in the southern hemisphere, and return in both cases in the opposite directions in the afternoon, were facts known before the establishment of the magnetic observatories; but M. De la Rive's explanation of them appears to have been suggested, and its appropriateness, as he considers, is shown, by its affirmed accordance with the remarkable peculiarity in the phenomena made known to us by the observations at the Magnetic Observatory at St. Helena, and communicated to the Royal Society in the paper referred to. This peculiarity is briefly as follows: the deviation which constitutes the principal part of the diurnal variation at St. Helena is *not uniform in its direction throughout the year*; in one part of the year it is to the west, and in the other part of the year to the east; and consequently during certain months of the year the movement of the magnet is in the *contrary direction* to that which prevails at the same hours during the other months of the year.

Now St. Helena is situated within the tropics, and M. De la Rive infers from his theory that in all places so situated, the diurnal variation should be in one direction when the sun's declination is north of the latitude of the place, and in the contrary direction when the sun's declination is south of the latitude of the place: and hence he too hastily concludes that his theory accords with the characteristics of the diurnal variation at St. Helena. When however the facts are more closely examined, it is seen that they do by no means accord with M. De la Rive's supposition.

That it may be quite clear that I do not misapprehend either M. De la Rive's theory, or his supposition in regard to the facts at St. Helena, I subjoin his own expressions, which convey his meaning, as that gentleman's writings generally do, with most commendable precision.

The first extract defines the limit which, according to his theory, should separate the electric currents proceeding respectively from each of the poles to the equator; and should consequently separate the parts of the globe in which the diurnal variation is in the one direction, from the parts in which it is in the opposite direction;

whilst the second extract describes what he believes to be the facts of the phenomena at St. Helena.

Extract 1.

"La limite qui sépare les régions occupées par chacun de ces deux grands courants n'est pas l'équateur proprement dit, car elle doit être variable : elle est, d'après la théorie que je développe, celui des parallèles compris entre les tropiques, qui a le soleil à son zénith ; elle change par conséquent chaque jour."

Extract 2.

"À St. Hélène, la variation diurne a lieu à l'ouest tant que le soleil est au sud de l'île, à l'est dès que le soleil est au nord. En effet, dans le premier cas, ainsi que j'ai remarqué plus haut, St. Hélène doit faire partie de la région dans laquelle les courants électriques vont sur la surface de la terre du pole boréal aux régions équatoriales ; et, dans le second cas, de la région dans laquelle ces courants vont du pôle austral vers l'équateur."

Whoever will be at the pains to refer to the paper printed in the Philosophical Transactions, describing the phenomena at St. Helena, or to the volume containing the details of the observations on the diurnal variation in each month during the five years in which hourly observations were maintained day and night at that observatory, will perceive,—on evidence which admits of no uncertainty,—that the two portions of the year in which the diurnal variation is in contrary directions at that island, are not determined, as M. De la Rive supposes, by the declination of the sun relatively to the *latitude of the place*, but by the declination of the sun relatively to the *equinoctial line*. The sun is vertical at St. Helena, passing to the south in the first week of November ; and again when passing to the north in the first week of February : consequently the two portions into which the year is thus divided, are respectively the one of *three*, and the other of *nine* months' duration ; but the actual portions in which the contrary diurnal movements of the magnets take place at St. Helena are of *equal* duration, and consist of *six* months and *six* months ; the dividing periods coinciding unequivocally, not with the sun's verticality at St. Helena, but with the equinoxes.

2. But if M. De la Rive's explanation be thus inconsistent in respect to the dates of the transition periods of the phenomena at St. Helena, it must be regarded as altogether at variance with, and opposed to, the phenomena described in the same paper at the Cape of Good Hope, where also they have been observed at the Magnetic Observatory at that station with an exactness which leaves no uncertainty whatsoever as to the facts themselves. The Cape is *not* situated within the tropics ; its latitude is 33° 56′ south ; the sun is consequently throughout the year well to the north of its zenith ; and therefore, according to M. De la Rive's theory, the deviations should be in one and the same direction throughout the year. But the fact is not so ; for the same contrariety in the direction of the diurnal variation at different portions of the year takes place at the Cape as at St. He-

lena; the two portions of the year in which the opposite phenomena prevail, are also identical at the two stations; and at both the change in the direction of the deviation takes place when the sun crosses the equinoctial line; the deviation being to the west at both stations when the sun is in the northern signs, and to the east when he is in the southern signs.

3. But in considering a theory which comes before us, claiming the high distinction of affording a physical explanation of facts which are known to us by well-assured observation, we ought not to confine our view to those points only for which it professes to supply the explanation: these are certainly tests as far as they go;—and in the present instance the conclusion from them is not favourable to the theory proposed;—but we should also notice the deficiencies of the theory; or those points wherein it neither furnishes, nor attempts to furnish, explanations of circumstances which are certainly amongst the most remarkable facts of the case. They may be possibly amongst the most difficult to explain; but no physical theory can be regarded as meeting the facts which does not at least attempt an explanation of them. I may name as the most prominent in interest amongst these the striking fact, that the Cape of Good Hope should be one of the stations at which this remarkable peculiarity, of a contrariety of movement at different periods of the year, takes place.

It is known that it does not occur at places situated in corresponding latitudes north of the geographical equator; at Algiers, for example,—which is moreover nearly in the same geographical meridian as the Cape, and where the magnetic inclination is nearly the same towards the north as is the case at the Cape towards the south. It may be quite correct perhaps to view the corresponding phenomena at St. Helena and the Cape as those belonging to *magnetically*-equatorial stations; but they are certainly not those peculiar to or characteristic of *geographically*-equatorial stations, which would be the condition in M. De la Rive's theory. There are thus two parts in the problem which await a physical explanation; on the one hand, the cause is required of the contrariety of movement, as well as of the times at which the different movements occur, the latter having obviously a dependence on the sun's position whether in the northern or the southern signs; and on the other hand, the cause must be shown why certain stations are thus affected and others not: a distinction which obviously does not depend on situation in regard to the geographical equator or to the tropical divisions of the globe.

I have myself been led to infer that the peculiarity in question results from and is indicative of proximity to the line of *least magnetic force*, regarded as physically the separating line on the surface of the globe between the northern and southern magnetic hemispheres; under this explanation the peculiarity would be strictly a magnetically-equatorial one.

It results from the present position of the four points of maximum intensity at the surface of the earth, that the intermediate line of least intensity departs considerably in the Southern Atlantic from the middle or geographically-equatorial portion of the globe, and passes

between the Cape and St. Helena, and consequently not far from either of those stations.

As far as I have yet been able to examine, I have found that the same remarkable peculiarity does exist at all other stations which are near this line, and at none which are remote from it. But however this may be, the accordance of the phenomena at the Cape of Good Hope and St. Helena, and their dissimilarity from those at other stations is a well-ascertained fact, of far too much bearing and importance to be passed without notice; and we may safely anticipate that its cause must occupy a prominent place in the theory which shall be ultimately received, as affording an adequate solution of the problem of the diurnal variation.

Believe me, my dear Sir, sincerely yours,

EDWARD SABINE.

S. H. Christie, Esq., Secretary to the Royal Society.

May 24, 1849.

The EARL OF ROSSE, President, in the Chair.

The following papers were read:—

1. An appendix to a paper "On the Variations of the Acidity of the Urine in the State of Health"—"On the Influence of Medicines on the Acidity of the Urine." By Henry Bence Jones, M.D., M.A., F.R.S. &c.

The variations of the acidity of the urine in the state of health having been shown in the original paper, and the effect of dilute sulphuric acid also traced; in this appendix, the influence of caustic potash, of tartaric acid, and of tartrate of soda, on the acidity of the urine is determined.

One ounce of liquor potassæ, specific gravity 1072, was taken in distilled water, in three days. It hindered the acidity of the urine from rising, long after digestion, to the height to which (from comparative experiments) it otherwise would have done; but it, by no means, made the urine constantly alkaline; nor did it hinder the variations produced by the state of the stomach from being very evident.

354 grains of dry and pure tartaric acid dissolved in water were taken in three days. The conclusion from the observations is that this quantity increased the acidity of the urine, but during that time it did not render the effect of the stomach on the reaction of the urine less apparent than when no acid was taken; and therefore, that this quantity of tartaric acid, during this time, does not produce so much effect on the reaction of the urine as the stomach does.

Tartrate of potash in large doses produces the most marked effect on the alkalescence of the urine. 120 grains of pure dry tartrate of potash dissolved in four ounces of distilled water made the urine alkaline in thirty-five minutes. In two hours the alkalescence had

disappeared, but after the next meal the effect of the tartrate of potash was again apparent. 10 drachms of tartrate of potash taken in three days produced but little, if any effect, on the acidity of the urine twenty-four hours after the last dose was taken.

2. "On the direct production of Heat by Magnetism." By W. R. Grove, Esq., M.A., V.P.R.S. &c.

The author recites the experiments of Messrs. Marrian, Beatson, Wertheim and De la Rive on the phenomenon made known some years ago, that soft iron when magnetized emitted a sound or musical note.

He also mentions an experiment of his own, published in January 1845, where a tube was filled with the liquid in which magnetic oxide had been prepared, and surrounded by a coil; this showed, to a spectator looking through it, a considerable increase of the transmitted light when the coil was electrized.

All these experiments the author considers go to prove that whenever magnetization takes place a change is produced in the molecular condition of the substances magnetized; and it occurred to him that, if this be the case, a species of molecular friction might be expected to obtain, and by such molecular friction heat might be produced.

In proving the correctness of these conjectures difficulties presented themselves, the principal of which was, that with electro-magnets the heat produced by the electrized coil surrounding them, might be expected to mask any heat developed by the magnetism. This interference, after several experiments, the author considers he entirely eliminated by surrounding the poles of an electro-magnet with cisterns of water, and by this means and by covering the keeper with flannel, and other expedients, he was enabled to produce in a cylindrical soft-iron keeper when rapidly magnetized and demagnetized in opposite directions a rise of temperature several degrees beyond that which obtained in the electro-magnet, and which therefore could not have been due to conduction or radiation of heat from such magnet. A series of experiments with this apparatus is given.

By filling the cisterns with water colder than the electro-magnet, the latter could be cooled by the water while the keeper was being heated by the magnetization.

The author subsequently obtained distinct thermic effects in a bar of soft iron placed opposite to a rotating permanent steel magnet, using a delicate thermo-electrical apparatus placed at his disposal by Mr. Gassiot.

To eliminate the effects of magneto-electrical currents, the author then made similar experiments with non-magnetic metals and with silico-borate of lead, substituted for the iron keepers, but no thermic effects were developed.

He then tried the magnetic metals nickel and cobalt, and obtained thermic effects with both, and in proportion to their magnetic intensity.

Some questions of theory suggested by the above experiments

and relating to the rationale of the action of what are termed 'the imponderables' and to terrestrial magnetism, are then briefly discussed, and the author concludes by stating that he considers his experiments prove satisfactorily, that whenever a bar of iron or other magnetic metal is magnetized, its temperature is raised.

June 7, 1849.

The Annual Meeting for the election of Fellows was held this day,—

The EARL OF ROSSE, President, in the Chair.

His Lordship addressed the Society.

On the motion of the Marquis of Northampton, seconded by Sir Robert Harry Inglis, Bart., the thanks of the Society were voted to the President for his admirable Address.

The Statutes relative to the election of Fellows having been read,—

Mr. William Tooke moved the following resolution:—

"That the election of Fellows be adjourned until Thursday the 21st instant at three o'clock, and that it be recommended to the Council that the list for such election shall comprise the names of all the Candidates, designating those selected by the Council in such manner as may be deemed fit."

The resolution having been seconded by Dr. John Lee, the Marquis of Northampton moved the following amendment, which was seconded by Sir Henry De la Beche:—

"That the Society do now proceed to the election of Fellows."

The amendment, having been put from the Chair, was declared to be carried.

Sir Henry De la Beche and Mr. Gray were, with the consent of the Society, appointed Scrutators to assist the Secretaries in examining the lists.

The votes of the Fellows present having been collected, the following gentlemen were declared duly elected:—

John Couch Adams, Esq.
Thomas Andrews, M.D.
Robert Alfred Cloyne Austen, Esq.
Charles Barry, Esq.
Benjamin Collins Brodie, Esq.
John Dalrymple, Esq.
James Glaisher, Esq.
Sir Robert Kane, M.D.
William Lassell, Esq.
Henry Beaumont Leeson, M.D.
Andrew Crombie Ramsay, Esq.
John Scott Russell, Esq.
Francis Sibson, M.D.
Robert Stephenson, Esq.
Lieut.-Col. Philip Yorke.

On the motion of Sir Charles Lemon, Bart., seconded by the Marquis of Northampton, it was unanimously resolved,—

"That the Noble President be requested to communicate to the

Government of the United States the expression of the thanks of the Royal Society for the steps taken to ascertain the fate of the expedition under Sir John Franklin, F.R.S., and to afford relief if it shall be necessary."

June 14, 1849.

The EARL OF ROSSE, President, in the Chair.

His Lordship announced, that in accordance with the resolution of the Society, requesting him to communicate the thanks of the Society to the Government of the United States for the steps taken by them to ascertain the fate of the Expedition under Sir John Franklin, he had addressed the following letter to His Excellency the American minister:—

MY DEAR SIR, 3 Connaught Place, June 8, 1849.

I have the honour to inform you, that at the annual meeting of the Royal Society, held the 7th inst., a communication was read from Admiral Sir Francis Beaufort, in which he apprised the Society that the American Government had nobly undertaken to send an expedition in search of Sir John Franklin. Upon which a vote of thanks was moved by Sir Charles Lemon, seconded by Lord Northampton, and carried with the utmost enthusiasm, expressive of the gratitude of the Royal Society to the American Government, and of their deep sense of the kind and brotherly feeling which had prompted so liberal an act of humanity. Allow me to assure you, that it is peculiarly gratifying to me to have the honour of being the humble instrument in conveying to you the thanks of the Royal Society on this occasion, and permit me to express a hope that this most generous act of the United States may, if possible, draw closer the bonds of friendship between the two kindred nations.

That the United States may continue to progress with the same extraordinary rapidity in the arts of peace and civilization, and to hold the same high place in the science and literature of the world, is I am sure the anxious desire of the Royal Society.

I have the honour to be,
My dear Sir,
Your most obedient humble Servant,
ROSSE, P.R.S.

The following papers were read:—

1. "On Carbonate of Lime as an ingredient of Sea-water." By John Davy, M.D., F.R.S. Lond. & Ed., Inspector-General of Army Hospitals, &c.

The manner in which limestone cliffs rising above deep water are worn by the action of the sea, as it were by a weak acid, such as we know it contains, viz. the carbonic—the manner, further, in which the sand on low shores where the waves break, becomes consolidated, converted into sandstone, by the deposition of carbonate of lime

from sea-water owing to the escape of carbonic acid gas,—are facts clearly proving that carbonate of lime is as a constituent of sea-water neither rare of occurrence, nor unimportant in the œconomy of nature, inasmuch as the phænomena alluded to,—the one destructive, the other restorative,—have been observed in most parts of our globe where geological inquiry has been instituted.

Reflecting on the subject, it seemed to me desirable to ascertain whether carbonate of lime as an ingredient of sea-water is chiefly confined to the proximity of coasts, or not so limited enters into the composition of the ocean in its widest expanse.

On a voyage from Barbados in the West Indies to England in November last (1848), I availed myself of the opportunity to make some trials to endeavour to determine this, the results of which I shall now briefly relate.

First, I may mention that water from Carlisle Bay in Barbados, tested for carbonate of lime, gave strong indications of its presence; thus a well-marked precipitate was produced by ammonia, after the addition of muriate of ammonia in excess, that is, more than was sufficient to prevent the separation of the magnesia which enters so largely into the composition of sea-water; and a like effect was produced either by boiling the water so as to expel the carbonic acid, or by evaporation to dryness and resolution of the soluble salts.

On the voyage across the Atlantic, the test by means of ammonia and muriate of ammonia was employed, acting on about a pint of water taken from the surface. The first trial was made on the 15th of November, when in latitude 20° 30′ N., and longitude 63° 20′ W., more than a hundred miles from any land; the result was negative. Further trials were made on the 22nd of the same month in lat. 32° 53′, long. 45° 10′; on the 24th, in lat. 36° 23′, long. 37° 21′; on the 25th, in lat. 37° 21′, long. 33° 34′; on the 26th, in lat. 38° 28′, long. 30° 2′; on the 27th, when off Funchal of the Western Islands, in lat. 38° 32′, long. 28° 40′, about a mile and a half from the shore, the water deep blue, as it always is out of soundings: in all these instances likewise the results were negative; the transparency of the water was nowise impaired by the test applied. The last trial was made on the 3rd of December, when in the Channel off Portland Head, about fifteen miles; now, slight traces of carbonate of lime were obtained, a just perceptible turbidness being produced.

The sea-water from Carlisle Bay, the shore of which and the adjoining coast are calcareous, yielded about 1 per 10,000 of carbonate of lime, after evaporation of the water to dryness, and the resolution of the saline matter. A specimen of water taken up on the voyage off the volcanic island of Fayal, about a mile from land, yielded a residue which consisted chiefly of sulphate of lime, with a very little carbonate of lime,—a mere trace; acted on by an acid it gave off only a very few minute air-bubbles. A specimen taken up off Portland Head, about fifteen miles, yielded on evaporation and resolution of the saline matter only a very minute residue, about ·4 only per 10,000; it consisted in part of carbonate and in part of sulphate of lime.

What may be inferred from these results? Do they not tend to prove that carbonate of lime, except in very minute proportion, does not belong to water of the ocean at any great distance from land? And, further, do they not favour the inference, that when in notable proportion, it is in consequence of proximity to land, and of land, the shores of which are formed chiefly of calcareous rock? In using the word proximity, I would not limit the distance implied to a few miles, but rather to fifty or a hundred, as I am acquainted with shores consisting of volcanic islands in the Caribbean sea destitute of calcareous rock, on which, in certain situations, sandstone is now forming by the deposition from sea-water of carbonate of lime.

Should these inferences be confirmed by more extensive inquiry, they will harmonize well with the facts first referred to, the solvent power, on one hand, of sea-water impregnated with carbonic acid on cliffs of calcareous rock in situations not favourable to the disengagement of carbonic acid gas; and the deposition, on the other hand, of carbonate of lime to perform the part of a cement on sand, converting it into sandstone, in warm shallows, where the waves break under circumstances, such as these are, favourable to the disengagement of this gas; and, I hardly need add, that the same inferences will accord well with what may be supposed to be the requirements of organization, in the instances of all those living things inhabiting the sea, into the hard parts of which carbonate of lime enters as an element.

Apart from the œconomy of nature, the subject under consideration is not without interest in another relation,—I allude to steam navigation. The boilers of sea-going steam-vessels are liable to suffer from an incrustation of solid matter firmly adhering and with difficulty detached, liable to be formed on their inside, owing to a deposition which takes place from the salt water used for the production of steam. On one occasion that I examined a portion of such an incrustation taken from the boiler of the "Conway," a vessel belonging to the West Indian Steam Packet Company, I found it to consist principally of sulphate of lime, and to contain a small proportion only of carbonate of lime. This vessel had been employed previously in transatlantic voyages, and also in intercolonial ones, plying between Bermudas and the Island of St. Thomas, and in the Caribbean sea and the Gulf of Mexico.

The composition of this incrustation, like the preceding results would seem to denote, if any satisfactory inference may be drawn from it, that carbonate of lime is in small proportion in deep water distant from land, and that sulphate of lime is commonly more abundant. The results of a few trials I have made, whilst rather confirmatory of this conclusion, showed marked differences as to the proportion of sulphate of lime in sea-water in different situations. That from Carlisle Bay was found to contain 11·3 per 10,000. A specimen taken up in lat. 29° 19′ and long. 50° 45′, yielded about 2 per 10,000, with a trace of carbonate of lime. A specimen taken up off Fayal yielded about 9 per 10,000, also with a trace of carbonate of lime. One taken up off Portland Head, about fifteen miles

distant, yielded, as already remarked, only 4 per 10,000, part of which was sulphate, part carbonate of lime.

By certain management, I am informed, as by not allowing the sea-water in the boilers to be concentrated beyond a certain degree, the incrustation, in the instances of the transatlantic steamers, is in a great measure prevented. Perhaps it might be prevented altogether, were sea-water never used but with this precaution, and taken up at a good distance from land, and in situations where it is known that the proportion of sulphate of lime is small. If this suggestion be of any worth, further, more extensive and exact inquiry will be requisite to determine the proportion of sulphate of lime in different parts of the ocean, and more especially towards land. By the aid of the transatlantic steam navigation companies means for such an inquiry may easily be obtained; and it can hardly be doubted that the results will amply repay any cost or trouble incurred.

Lesketh How, Ambleside,
March 29, 1849.

2. "On the Universal Law of Attraction, including that of Gravitation, as a particular case of approximation deducible from the principle that equal and similar particles of matter move similarly, relatively to each other." By John Kinnersley Smythies, Esq. Communicated by T. F. Ellis, Esq., F.R.S.

After stating the general object of his investigations and explaining the notation he employs, the author enters upon some preliminary geometrical inquiries. He gives the equation between the six right lines drawn between four points in a plane; the solidity of a tetrahedron in terms of its edges: the equation between the cosines of the six angles made by four right lines meeting in a point; and the equation between ten right lines drawn between five points, with some formulæ of verification. Giving some general rules for the transformation and consolidation of series, he transforms the last equation into one involving the solidities of tetrahedrons, and shows how the sign of each tetrahedron in that equation is determined by its position relatively to the least solid including them all; and then gives the equation between all the right lines drawn between n points.

Having shown that the result of differentiating the product of n variables, m times successively may be derived from the mth power of the sum of the n variables, developed by the polynomial theorem by substituting for every power of each variable its differential of an order numerically the same as the power; and applied the theorem to find the differential of the mth order of the equation between ten right lines drawn between five points; the author gives the first four successive differentials of the same equation in another form.

Proceeding with his investigation he deduces the necessary equation between the distances and central forces of five moving points, and derives from it the general system of equations which determine the motion of any number of spheres in terms of ϕ (the function of the distance according to which the attractive force varies), their

masses and mutual distances. After proving that any number of spheres may move so that the central force shall vary directly as the distance, he shows that only certain values of φ are possible for an infinite number of spheres, giving the criterion of possibility; and thence that the only possible law of central force for an infinite number of spheres is that in which the force varies directly as the distance.

The author then enters upon some general considerations on the physical impossibility of an universal law, rigorously exact and expressed by equations involving differentials of no higher order than the second, and on the amount of disturbance by extraneous agencies. Having shown how all equations expressed by rectangular coordinates may be transformed into others involving only the mutual distances of the spheres at m equal intervals of time, he gives an equation of differences defining the motion of n points, such that the distances and their differentials of every order not exceeding m may have any assigned values.

After deducing a general formula for transforming equations of differences not exceeding the mth order into equations between the distances at m equal intervals of time, the author applies it to the last equation, and shows that the equations so found are possible for any number of moving points and for every value of m; and that the most general law, by which the motion of n equal spheres can be determined, so that all move according to the same law at all times, may be found by taking a proper value of m. He then shows that these equations give a method of unlimited approximation to any unknown law; and suggests the mode of extending the solution of the problem to solids of any figure and mass. Finally, he gives the mth differential of the distance between any pair of points moving according to this law, in terms of the differentials of lower orders including the distances.

June 21, 1849.

The EARL OF ROSSE, President, in the Chair.

The following Gentlemen were admitted into the Society:—

Sir Robert Kane, M.D.; Thomas Andrews, M.D.; John Scott Russell, Esq.

The Right Rev. The Lord Bishop of Manchester was elected into the Society.

The following papers were read:—

1. "On the Anatomy and Affinities of the Family of Medusæ." By Henry Huxley, Esq. Communicated by the Bishop of Norwich, F.R.S.

The author commences by remarking that no class of animals has been so much investigated with so little satisfactory and comprehensive result as the family of *Medusæ* (including under that name the *Medusæ*, *Monostomatæ* and the *Rhizostomidæ*), and proposes in this

paper to give a connected view of the whole class considered as organized upon a given type, and an inquiry into its relations with other families. This he has been enabled to do through numerous and peculiar opportunities for the investigation of these animals, enjoyed during a cruise of some months along the eastern coast of Australia and in Bass's Strait*.

The memoir is divided into two sections, of which the first treats of the anatomy of the Medusæ, and the second of their affinities.

The organs of the Medusæ are formed out of two distinct membranes—foundation membranes. Both are cellular, but the inner is in general softer, less transparent and more richly ciliated than the outer, but contains fewer thread-cells. The outer is dense, transparent, and either distinctly cellular or developed into a muscular membrane. It may be ciliated or not, and is usually thickly beset with thread-cells, either scattered through its substance or concentrated upon more or less raised papillæ developed from its surface. When the stomach is attached to the disc, the outer membrane passes into the general substance of the disc, while the inner becomes continuous with the lining membrane of the canals. There is a larger or smaller space, termed by the author the "common cavity," between the inner aperture of the stomach and the openings of the canals, with which both communicate. This is the structure of the stomach in the Cryptocarpæ and Phanerocarpæ; in the Rhizostomidæ it is fundamentally the same, but the stomachs are very minute, and collected on the edges and extremities of the ramuscules, a common stem. The Rhizostomes, *quoad* their digestive system, have the same relation to the Monostome Medusæ that the Sertularian Polypes have to the Hydræ, or the Coralline Polypes to the Actiniæ. In consequence of a very irritable contractile membrane surrounding and overlapping the orifices of their stomachs, they are seen with difficulty. This membrane consists of two processes, one from each side of the perforated edge of the branch. In *Rhizostoma* they generally remain distinct, but in *Cephea* they are frequently united in front of and behind each aperture so as to form a distinct polype-like cell. In the structure of the disc there exists no difference between the Monostome and Rhizostome Medusæ. The author gives an account of his observations on the minute structure of the disc. The arrangement of the cavities and canals of the disc differs in the different sections. In very many of the Cryptocarpæ there is a circular, valvate, muscular membrane developed from the inner and under edge of the disc. In the Phanerocarpæ such a membrane does not seem to be present, but in *Rhizostoma* and *Cephea* it is evidently replaced by the inflexed edge of the disc. In the Cryptocarpæ the marginal corpuscles are sessile upon the circular vessel. They are spheroidal vesicles, containing a clear fluid, and one or more strongly-refracting bodies occasionally included within a delicate cell. The marginal vesicles are placed between

* Mr. Huxley is Assistant-Surgeon to H.M.S. Rattlesnake, now engaged on a surveying voyage conducted by Capt. Stanley on the coasts of Australia and New Guinea.

the inner and outer membranes of the circular vessel. In the Phanerocarpæ the marginal corpuscles are pedunculated and protected by a semilunar fold. The author describes peculiarities in this part of the organization of *Rhizostoma*. The excretory orifices, described by Ehrenberg as general in *Medusa aurita*, were not detected by the author in *Cephea ocellata*. Nor does he admit the supposed nerves and intertentacular ganglia of that author to be such.

Paragraphs 29 to 36 are occupied by a minute description of the tentacles of Medusæ.

The generative organs of the three groups of Medusæ are always portions more or less developed of the walls of the system of canals, and consist of the two "foundation" membranes, in or between which the generative elements, whether ova or spermatozoa, are developed. This the author concludes from his observations on several genera, which he gives in detail, and which add considerably to, and differ in some respects materially from, what has been stated by previous observers. In the ovarium, the two membranes develope between them immense multitudes of ova with a dark granulous yelk and clear germinal vesicle. The ova are attached to the outer surface of the inner membrane. In the testis the inner membrane is produced into a vast number of thick pyriform sacs, which lie between the two membranes, with their blind ends towards the inner surface of the outer membrane; internally, they open each by a distinct aperture on the fine surface of the inner membrane. The contents of the sacs are spermatozoa, and cells in every stage of development towards spermatozoa, which appear to be formed by the elongation of the secondary cells contained in the large cells.

The author's observations lead him to believe that the muscular fibres are always developed in the outer "foundation" membrane. Each fibre in *Rhizostoma* is made up of very small and indistinct fibrils, which are transversely striated. He has not observed any indubitable trace of a nervous system in the Medusæ, nor of the so-called blood-vascular system described by Will.

In this section of the memoir the affinities of the Medusæ are considered. In their essential characters,—viz. their construction out of two membranes inclosing a variously-shaped cavity; their generative organs being external and variously developed processes of the two membranes; and the universal presence of the peculiar organs called thread-cells,—they present a striking resemblance to other families of Zoophytes, as the Hydroid and Sertularian Polypes, the Physophoridæ and the Diphydæ The disc of a *Medusa* is represented by the natatorial organ among the Diphydæ and Physophoridæ, but has no homologue among the Hydræ and Sertulariæ. The cell of the Sertularian Polype rather resembles the "bract" of the Diphydæ than the natatorial organ, and the latter family forms a connecting link between the Medusæ and the Physophoridæ. Of the two kinds of tentacles in the Medusæ, the first is represented in the Physophoridæ and Diphydæ, by the thickenings, richly beset with thread-cells, that frequently occur in the lip of the stomach; in the Sertularian Polypes by the tentacles of the margin

of the mouth. The second kind is homologous with the prehensile organs of the Diphydæ and Physophoridæ, and with the peculiar clavate processes of *Plumularia*. All these organs commence their development as bud-like processes of the two joining membranes. The peculiar clavate organs of *Plumularia* are developed from the common tube independently of the stomach. They have not been hitherto described, and were observed by the author in two species of *Plumularia* dredged at Port Curtis. They were of two kinds, the one attached to the cell of the polype, the other to the pedicle of the ovary. To each species there were three processes of the former kind, two above proceeding from near that edge of the aperture which is towards the stem, the other below from the front part of the base of the cell. They were conical in one species, club-shaped and articulated in the other, and consisted of an external horny membrane open at the apex, and an internal delicate membrane inclosing a cavity, all these being continuous with the corresponding parts of the stem. At the apex of each, and capable of being pressed through the aperture, lay a number of thread-cells. The second kind of organ was present in the species with conical processes. It consisted of a stem proceeding from the pedicle of the ovary, bearing a series of conical bodies, having the same constitution as those just described; the whole bearing a close resemblance to the prehensile organs of the Diphydæ.

The following table exhibits the homologies of the several families, which must be regarded as by no means so distinct as hitherto supposed, but rather as members of one great group, organized upon one simple and uniform plan, and even in their most complex and aberrant forms reducible to the same type.

Stomachs identical in Structure throughout.

Medusæ.	*Physophoridæ.*	*Diphydæ.*	*Sertularidæ.*	*Hydræ.*
Disc	Natatorial organ	Natatorial organ.		
Canals	Canals of natatorial organ	Canals of natatorial organ.		
Common cavity	Common tube	Sacculus and common tube	Cavity of stem.	
Canals of branches (*Rhiz.*)				
		Bract	Polype-cell.	
Tentacles, 1.	Thickened edge of stomach		Oval tentacles.	
2.	Prehensile organs		Clavate organs	Tentacles (?).
Generative organs	Generative sac		Generative organ	Generative organ.
	Natatorial organ of generative sac			Natatorial organs (Coryne).
Marginal vesicle	?		?	?

2. "Memoir to accompany a Map of the Magnetic Variation for 1840 in the Atlantic Ocean between the parallels of 60° N. and 60° S. latitude, being Contributions to Terrestrial Magnetism, No. 9." By Lieut.-Colonel Edward Sabine, R.A., For. Sec.R.S., and printed in the Philosophical Transactions.

In this Number of the Magnetic Contributions the author gives maps of the Magnetic Declination in the Atlantic in January 1840, between the parallels of 60° N. and 60° S. lat., founded on 1480 de-

terminations, by observers of different nations, all comprised between the years 1828 and 1848; each determination being in the majority of cases a mean of several distinct and independent observations, and all reduced to the epoch of 1840, by the rates of secular change derived from a comparison of Hansteen's map of 1787 with the present state of the phenomena.

A considerable portion of the determinations thus co-ordinated having been obtained on board ships in which measures were taken to supply the means of correcting the errors occasioned by the influence of the iron which the ships contained, the author in an accompanying memoir has discussed at some length the *variable* part of the corrections required for that purpose, being that portion of the correction which varies as a ship changes her geographical position. He infers from the observations generally, and especially from those of H.M.S. Erebus during the Antarctic Expedition in 1839–1843, that the disturbance occasioned by the iron is chiefly, if not entirely, due in wooden ships to the induced magnetism of the iron; but that its changes are not so rapid as those of the terrestrial magnetic Inclination and Force during changes of geographical position, and that the magnetism of the ship is consequently at such times liable to become more or less *in arrear*, if the expression may be permitted, of the change which the magnetic inclination and force have undergone; that in fact there are considerable portions of a ship's iron which are not permanently magnetic on the one hand, nor perfectly soft so as to undergo instantaneous change with changes of inclination and force on the other hand; and which derive magnetism by induction from the earth, but conform *gradually* rather than *instantaneously* to the changes of terrestrial magnetism corresponding to changes in the ship's place.

The bearing which this new view of a ship's magnetism would have on the endeavour to counteract the disturbance occasioned by the iron, either by permanent magnets or by soft iron, is noticed, and the conclusion is arrived at, that in order to correct magnetic observations made on board ship, it is desirable to determine experimentally the variable term in the correction formulæ, at intervals of not many days apart when a ship is changing her geographical position. An apparatus and method of observation to accomplish this purpose are described, which are stated to be extremely simple, to require no unusual circumstances of weather and no reference to celestial objects, and to occupy but a very few minutes.

In conclusion, a comparison is instituted between the declinations computed by M. Gauss's general theory and those now derived from observation over a field of considerable extent; and on this comparison the author founds the following remark, "that the general theory will require to have its numerical coefficients reconstructed before it can become available for practical purposes; and that those who desire to take a correct view of the magnetic phenomena, must for the present at least, have recourse to the maps constructed directly from the observations themselves."

3. "On the Microscopic Structure of the Scales and Dermal Teeth of some Ganoid and Placoid Fish." By W. C. Williamson, Esq. Communicated by Edwin Lankester, M.D., F.R.S.

The author commences his paper by stating that the structure and modes of growth of fish-scales have been studied by many observers, especially by Leeuwenhoek, Agassiz, Mandl and Owen. The first of these considered each scale to consist of numerous superimposed laminæ added successively to the inferior surface. This view has been revived, with some important modifications, by M. Agassiz, and especially applied to the scales of ganoid fish; which he showed to consist of laminæ of true bone, usually covered with enamel (*émail*), the latter often resembling the dentine of fishes' teeth. M. Mandl denied that ganoid scales had been formed by such successive additions of laminæ; and Professor Owen also opposed the idea, that they had merely been the result of successively excreted deposition. The author then proceeds to the examination of the scales of the following genera and species:—*Lepidosteus osseus*, *Lepidotus semiserratus*, *L. Mantelli*, and *L. fimbriatus*, *Seminotus rhombifer*, *Pholidotus Leachii*, *Ptycholepis Bollensis*, *Beryx*, *Dapidius orbis*, and *D. granulosus*; all of which appear to be constructed according to a common type—one singular modification of which is seen in *Palæoniscus comptus* and *P. Beaumonti*, and another in *Gyrodus* and *Aspidorhynchus acutirostris*. Still more elaborate complications occur in the scales of the Sturgeon and of *Platysomus parvulus*, the minute structure of which is described. Then follow detailed accounts of another interesting group of structures found in the genera *Megalichthys*, *Holoptychius* and *Diplopterus*, in which the osseous tissues and their superficial coverings are exceedingly beautiful and complicated. The next fish examined is *Macropoma Mantelli* from the chalk. In this the true bony operculum is studded over with dermal teeth, as is also the posterior part of each scale; the portion of the latter, however, which is subjacent to these dermal teeth, is not osseous, but consists of thin laminæ, which do not contain lacunæ. The hollow viscus found in the interior of the *Macropoma*, is shown to be a cylinder of true osseous tissue, of a singular laminated structure full of lacunæ. The author rejects the idea of its having been a stomach, but thinks that it may have served the purpose of an air-bladder.

The structure and arrangement of the dermal teeth from the skin of the Dog-fish are then investigated, and appear to resemble those on the opercular bones and scales of *Macropoma*. Similar teeth are described in the fossil skin of *Hybodus reticulatus*, from the lias of Lyme Regis. In the latter, numerous small granules of calcareous matter, having a concentric laminated structure, have been imbedded in the substance of the soft cutis, under the dermal teeth. The corresponding dermal teeth from the *Raia clavata* are described, and also those covering the snout of the common Saw-fish; as well as the very singular premaxillary bones of the *Cœlorhynchus*.

From an examination of the dermal appendages of the fishes thus cursorily enumerated, the author concludes—

That what has hitherto been termed enamel, is in fishes a compound structure, separable into ganoin and kosmine (*κόσμειν, to adorn*); the former being transparent and laminated, but otherwise structureless, whilst the latter consists of minute branching tubes resembling the dentine of true teeth.

That the kosmine covering the osseous scales of so many ganoid fish, as in *Lepidotus semiserratus*, *Megalichthys Hibberti*, &c., is homologous and identical with the substance composing the dermal teeth of the true placoids, such as the Dog-fish, Thornback, &c., only that, whilst in the former the areolæ of kosmine are aggregated upon bony scales, in the latter they are implanted in the soft integument, without the intervention of any bony matter. It follows from this, that the distinction of "ganoid" and "placoid" is scarcely a physiological one, inasmuch as the scales of many so-called ganoid fish, such as *Dapidius orbis*, *Acipenser*, &c., exhibit little or no trace of either ganoin or kosmine; that in many of the Placoids these substances are very largely developed; and that a series of well-defined links exist, passing through the common Thornback, the common Spotted Dog-fish, *Hybodus reticulatus*, *Macropoma Mantelli*, *Dapidius granulosus*, *Holoptychius*, *Diplopterus* and *Megalichthys*, by which the ganoid and placoid forms merge in one another.

That ganoid scales consist of variously modified osseous lamellæ, the result of successive additions made chiefly to the lower surface of each; but also, under particular circumstances, either to a part, or to the whole of the upper surface.

That these lamellæ have not been the result of any process of excretion, or depositions from a secreting surface, as supposed by M. Agassiz, but that they have been formed by the calcification of the lower laminæ of an investing vascular periosteum; and that consequently the phænomena attending the structure and growth of these ganoid scales contribute in a material degree to establish the correctness of the views recently promulgated by Professor Sharpey respecting the growth and development of human bone; the gradual formation of Haversian canals being traced with great ease from the simple laminæ seen in the scales of *Lepidosteus*, *Lepidotus*, &c., through *Aspidorhynchus*, *Acipenser*, *Holoptychius*, &c. to their high degree of development in *Megalichthys*.

That the study of the microscopic structure of the dermal appendages of fish may, when carried on with due caution, be made a valuable auxiliary, both in distinguishing between allied species, and in establishing the existence of important affinities, even when applied to otherwise insignificant fragments; but that it is capable of being overstrained, and of leading to erroneous conclusions, if any classifications are founded upon it irrespective of the other portions of the fish to which the scales belong, because of the unequal ratio in which the various parts of an organism may have been developed. Thus, whilst *Lepidosteus osseus* presents one of the simplest forms of ganoid scales, it has the concavo-convex vertebral articulations of the Ophidians; on the other hand, in many species, as in *Megalichthys* and *Holoptychius*, whilst the structure of each part of the exo-

skeleton is highly developed, the vertebræ appear to have the double concave articulation common amongst fish and enaliosaurs.

The author, in conclusion, acknowledges his obligations to Sir Philip M. de Grey Egerton, M.P., Dr. Mantell, Mr. Binney, Mr. J. E. Gray and Mr. Searles Wood, for their valuable co-operation in supplying many important specimens for examination.

4. "On the Mechanical Equivalent of Heat." By J. P. Joule, Cor. Associate R. Acad. Sciences, Turin, &c. Communicated by M. Faraday, D.C.L., F.R.S., Foreign Memb. Acad. of Sciences, Paris, &c.

After passing in review the experimental researches of Rumford, Davy, Dulong, Faraday, and others who have successively discovered facts tending to prove that heat is not a substance, but a mode of force, the author mentions the papers he has already communicated to the Royal Society, and published in the Philosophical Magazine, in which he has endeavoured to show that in the production of *heat* by the expenditure of *force*, and *vice versâ*, in the production of *force* by the expenditure of *heat*, a constant relation always subsists between the two. This relation he denominates the "Mechanical Equivalent of Heat," and the object of the present paper is to advance fresh proofs of its existence, and to give to it the numerical accuracy requisite to fit it as a starting-point for further inquiries.

In carrying out the above design, the author has determined the relation of *work done* to *heat produced* in the cases of the friction,—1st, of water; 2nd, of mercury; and 3rd, of cast iron.

In the experiments on the friction of the fluids, the liquid was contained in a covered cylindrical vessel of copper or iron, and the agitation was effected by vanes of brass or iron, fixed to a vertical axis revolving in the centre of the vessel, whilst fixed vanes prevented the liquid being whirled in the direction of rotation. In the experiments on the friction of solids, a disc of cast iron was rotated against another disc of cast iron pressed against it; the whole being immersed in a cast-iron vessel filled with mercury.

The *force expended* was measured by the descent of the weights employed in rotating the apparatus; and great care was taken to correct it for the friction of the axes of the pullies employed, &c.

The *heat evolved* by the friction was measured by exact thermometers, and very laborious precautions were taken in order to eliminate the effects of radiation or conduction of heat to and from the surrounding atmosphere. The corrected thermometric effect was then reduced to a known capacity for heat, by means of extensive series of experiments made in order to ascertain the specific heat of the materials in which the thermometric effect was observed.

In this way the number of units of work, estimated in pounds one foot high, required to be done in order to develope one degree Fahr. in one pound of water taken at about 50°, was found to be as follows:—

772·692 from friction of water, a mean of 40 experiments.
774·083 from friction of mercury, a mean of 50 experiments.
774·987 from friction of cast iron, a mean of 20 experiments.

5. "On the Nitrogenous Principles of Vegetables as the sources of artificial Alkaloids." By John Stenhouse, F.R.S.

After observing that there are few departments in organic chemistry which during the last six or seven years have attracted more of the attention of experimenters than the artificial formation of the alkaloids, and attributing this fact to the interesting nature of this class of bodies both as regards their well-defined chemical properties and the important medical virtues which many of them possess, the author proceeds to state, that although attempts to form the natural alkaloids, such as quinine, cinchonine, &c., by artificial means have hitherto been unsuccessful, yet chemists have been enabled by various processes to procure artificially a considerable number of true alkaloids very analogous to those which occur in nature. The various methods by which this has been effected, such as by acting on essential oils with ammonia, by the destructive distillation of coal and animal substances, &c., are then enumerated and described.

It is also remarked as somewhat singular, that while so many other sources have been examined, no attempt should have been made to procure alkaloids from vegetable albumen, fibrine, caseine, &c., which are so rich in nitrogen, and which occur in such abundance in many plants. What renders the neglect of these substances the more remarkable, is the consideration that coal has been one of the most productive sources of the alkaloids, yielding them, as it does, four other bases besides ammonia. Now as coal is universally admitted to be of vegetable origin, and to consist of the remains of a variety of extinct vegetables, the nitrogenous principles of which must be regarded as the sources of the bases which it yields, it seemed to the author not unreasonable to expect, that, by acting on the nitrogenous principles of recent vegetables, the same organic bases as those obtained from coal, or at any rate a series of analogous bases, would be obtained in still greater abundance; and it subsequently appeared that this latter expectation was not altogether without foundation.

From the difficulty of procuring vegetable albumen, fibrine, &c. in a state of even tolerable purity, those portions of plants (usually their seeds) were selected which contain those principles in the greatest abundance.

In the first instance, a quantity of *Phaseolus communis*, or common horse-bean, was destructively distilled in a cast-iron cylinder, and the products collected by means of a large condensing Liebig's apparatus. These products closely resembled those obtained from the distillation of bones and other animal matters, comprising among other substances acetic acid, empyreumatic oils, tar, a great deal of ammonia and several organic alkaloids. The crude product was supersaturated with muriatic acid, and the clear liquid decanted after the tar had subsided. The acid liquor was next passed through a cloth filter, which removed the greater portion of the resinous matter. The clear liquid was then poured into a capacious still, and supersaturated with carbonate of soda. When the liquid began to boil, much ammonia was disengaged, and a quantity of oily bases collected in the receiver. Their amount increased as the distillation proceeded. These bases were separated from the ammoniacal liquid

by means of a pipette, and were purified by suitable processes which it is unnecessary to particularize. These bases, though they were found to vary very considerably in their boiling-points and some of their properties, were very similar in other respects. They were transparent colourless oils, which were all of them lighter than water, and refracted light strongly. Their taste was hot, resembling that of oil of peppermint. They all exhibited strong alkaline reactions, and neutralized the acids perfectly, forming crystallizable salts. The most curious circumstance respecting them was, that they were apparently quite different from the series of bases obtained from either bones or coal, and contained no aniline.

One of these bases was isolated and subjected to analysis. It boiled between 150° and 155° C. Its formula was found to be C_{10} H_5 N, which differs only by two equivalents of hydrogen from nicotine. The only obstacle which has hitherto prevented the separation and examination of each of these bases individually, has arisen from the difficulty of procuring them in sufficient quantity. Not that beans when distilled yield bases in so much smaller quantities than bones and other animal substances; but as both bones and coal are distilled on the largest scale for commercial purposes, their crude oils may be easily procured in any quantity, and from these their respective series of bases may be readily prepared. In regard to the bases from beans and other seeds, the case is quite different; as the scientific chemist is compelled to distil these substances on purpose, an operation which cannot be conveniently conducted in a laboratory, since it requires an apparatus so large as to be almost upon a manufacturing scale.

Oil-cake.—As the *Phaseolus communis* was regarded as the type of the Leguminosæ, oil-cake, or the expressed seeds of *Linum usitatissimum*, was selected from that numerous class of plants in which the starch of the Gramineæ is replaced by oil. The products of its distillation were very similar to those from beans, containing however more ammonia and a somewhat smaller proportion of oily bases, which, though similar, appeared to differ from those of the preceding series. They were also equally devoid of aniline.

Wheat, *Triticum hybernum*, and subsequently peat from the neighbourhood of Glasgow, were also destructively distilled. Both of these substances, in addition to ammonia, yielded a series of oily bases, which also contained no aniline.

Distillation of wood.—The author proceeds to state, that through the kindness of an extensive pyroligneous acid manufacturer he was enabled to examine considerable quantities of the crude acid liquor obtained from the destructive distillation of beech, oak, and other hard woods. The stems and larger branches of trees are alone employed for this purpose. He found to his surprise that this acid liquor contained scarcely a trace of ammonia or of any other organic base, showing that the woody portions of the limbs and stems of trees are nearly devoid of nitrogenous matter, in which respect they differ extremely from peat, which in general contains two per cent. of nitrogen; and he considers this circumstance as perhaps calculated

to throw some light upon the origin of the coal-beds, which some geologists believe to have been formed from the submersion of forests and the floating of uprooted timber into estuaries and lakes, while others contend that they have been produced by the submersion of beds of peat. Irrespective therefore of other considerations, the author urges in favour of the latter opinion, that wood is not capable of furnishing the amount of nitrogen we find existing in coal, while peat contains rather more than double the quantity required. The expectation of procuring aniline, picoline, &c., the coal series of bases, from the distillation of peat, was disappointed; a result only to be accounted for on the hypothesis, that the different genera of plants, when destructively distilled, yield different series of organic bases.

From the facts which have previously been stated, the author considers himself warranted in concluding, that when ammonia is produced by the destructive distillation of either animal or vegetable substances, it is always accompanied with the formation of organic bases. Now as ammonia is known to be procurable from these substances by other methods than destructive distillation, it seemed highly probable that on these occasions organic bases would also be produced. Beans, oil-cake and flesh, were therefore successively boiled in a distilling apparatus with strong alkaline lyes. In every instance, in addition to ammonia, a series of organic bases was also produced. Similar results were also obtained when the above-mentioned substances were digested in strong sulphuric acid, the acid solution supersaturated with an alkali and subjected to distillation. The ammoniacal liquor which passed into the receiver was found invariably to contain organic bases.

Bases by putrefaction.—As putrefaction is almost the only other means by which ammonia is readily procurable in quantity from vegetable and animal substances, the effects of this process were also examined in the first instance in the case of guano. An aqueous solution of Peruvian guano was saturated with carbonate of soda and distilled. In addition to much ammonia, a quantity of basic oils was also obtained. Subsequent to this experiment, the effects of putrefaction on a quantity of horse-flesh were also examined, when a considerable amount of oily bases was found to have been generated.

From the facts which have now been enumerated, the author concludes "*that whenever ammonia is generated in large quantity from complex animal or vegetable substances, it is invariably accompanied by the formation of a larger or a smaller amount of volatile organic bases.*" If therefore researches similar to the present are actively prosecuted, and if the seeds and leaves of the various genera of plants are subjected to these or analogous processes, it seems not unreasonable to expect that the number of the organic alkaloids will ere long be considerably increased.

6. "On the Development and Varieties of the great anterior veins in Man and Mammalia." By John Marshall, Esq. Communicated by Professor Sharpey, F.R.S.

The object of this paper is to state the result of observations on

the metamorphosis of the great anterior veins in Man and Mammalia, and on the relations existing between the primitive and final condition of these vessels, in different cases, both in their normal arrangement in animals, and their abnormal condition in the human subject.

From an examination of the form and structure of the sinus of the great coronary vein, and of the arrangement of its branches and valves in Man and some of the Mammalia, and from a comparison of those parts with the terminations of the great coronary and other posterior cardiac veins in the other Mammalia, the *coronary sinus* in Man and one set of Mammals, as the Dog, Cat, and Seal, is shown to be *analogous to the lower part of the left vena cava anterior* found in another set, represented by the Elephant, Rabbit and Hedgehog, and to *the lower part of the left vena azygos*, found in a third set, as exemplified in the Sheep, Ox and Pig. The great coronary vein, therefore, is shown always to end in a similar way, viz. in a larger muscular venous channel, which, in all cases, ends in the right auricle of the heart, by a wide orifice situated in an exactly corresponding part of that cavity.

The author remarks that a similar view has recently been published by Bardsleben; but his own observations were completed, and his deductions arrived at, quite independently.

Reflecting on the above-mentioned analogies and on the known method of development of the great anterior veins in *all* the Vertebrata, as pointed out by Rathké, from four primitive lateral venous trunks, viz. two anterior or jugular, and two posterior or *cardinal* veins, the coronary sinus is demonstrated to be the lower persistent portion of the left anterior primitive venous trunk, next to the heart. By Rathké, however, the whole of this left primitive trunk, from the neck down to the heart, is supposed to become occluded and then entirely to disappear in Man, and in such animals as are similarly formed in respect to these great veins; but the author finds that not only does its lower part persist in a previous condition as the coronary sinus, but that other remnants or vestiges of this primitive venous channel are to be found throughout life in Man, and in those animals in which the great anterior veins undergo a like metamorphosis.

The inquiry thus opened is then systematically pursued, first, by tracing the details of the metamorphosis of the great anterior veins in the embryos of the Sheep and Guinea Pig, and in the human fœtus; secondly, by a comparison of the adult condition of these great veins in the entire class of Mammalia; and thirdly, by an examination of the occasional varieties of the same vessels met with in the human subject.

1. *Of the development of the great anterior veins.*—After describing at length the metamorphosis of these vessels, the author proceeds to give an account of the remnants of the left anterior primitive vein in the adult.

These are indicated by the following parts, traced from the summit of the left thoracic cavity down to the back of the heart. *Out-*

side the pericardium, certain fine bands of fibrous tissue, which descend beneath the pleura, from the trunk of the left superior intercostal vein to the front of the root of the left lung; and inside the pericardium, *a fold of the serous membrane* which passes down from the left pulmonary artery to the subjacent pulmonary vein,—certain *opaque lines or streaks* upon the side and back of the left auricle,—a small *oblique auricular vein* which is continued from those streaks down to the coronary sinus,—and lastly, the *coronary sinus* itself. The fold of the pericardium, which hitherto has escaped observation, is particularly described. It is named by the author the *vestigial fold of the pericardium*, or, from its having contained the canal of Cuvier in the embryo, the *Cuvierian fold*.

2. Under the second head, a *comparison* is instituted between the *great anterior veins of Man and the Mammalia* generally.

Having remarked that, as high up in the vertebrate scale as Birds, no fundamental alteration occurs from the primitive condition of two anterior and two posterior independent lateral venous trunks, the author remarks that in *all* Mammalia one *characteristic* change is met with, viz. the formation of a transverse branch across the root of the neck.

The right anterior primitive vein in all cases persists as the right or ordinary vena cava superior; but the left vein either remains unoccluded, and returns the blood from the left side of the head and neck, from the left upper limb, the left side of the thorax, and from the substance of the heart; or, owing to a partial occlusion, returns only the blood from the left side of the thorax and from the substance of the heart; or, owing to still further occlusion, from the substance of the heart alone. Hence three principal groups arise.

a. In the first group a right and a left superior vena cava exist, connected by a cross branch at the root of the neck, as in the Monotremata, Marsupialia, the Elephant, most Rodentia, the Hedgehog and the Bat.

b. In another group a right superior cava and a left vena azygos exist, as in the Sheep, Goat, Ox, Pig, Horse, Mole and Guinea Pig.

c. In the third group there is found, besides the right vena cava superior, only a left cardiac venous trunk or coronary sinus, together with the vestiges already described, as in the Cetacea, Carnivora and Quadrumana, as well as in Man.

In each of these groups subordinate varieties are shown and classified.

3. *The almost numberless varieties of the great anterior veins in the human subject* are then arranged on principles similar to those adopted in regard to the different conditions found among Mammalia; but the groups are arranged in the inverse order, and the usual condition of the veins in Man is included as a necessary element in the series.

In one large *class* of cases, comprehending *three groups* similar to those of the different Mammalia already defined, the cross branch in the neck is always present.

a. In the first group there is a right vena cava superior, and a left

cardiac venous trunk or coronary sinus. This is the ordinary condition. Further subdivisions arise, depending on peculiarities of the vena cava itself, which are rare; of the azygos system, which are exceedingly numerous; and of the coronary vein and sinus, which are again uncommon. Transposition occasionally produces a further modification, in which the superior cava is found on the left side; whilst the coronary sinus, the oblique vein and the vestigial fold of the pericardium, exist on the right.

b. In another group there might exist a right vena cava superior and a left vena azygos, as in the Sheep; but no example of this possible variety has yet been met with in the human subject.

c. In the third group a right and a left superior cava coexist, as in the Elephant, constituting what is termed a double vena cava superior. Thirty examples of this condition are adduced, of which eleven only have occurred in adult and otherwise perfect hearts. One of these was met with by the author, and is specially described.

Lastly, a separate or second *class* consists of those cases in which the cross branch is wanting, and which are, accordingly, destitute of the characteristic mammalian type, and present, as in Birds, the persistent condition of four independent lateral venous trunks.

The paper is illustrated by original drawings, of the development of the veins in the Sheep and in Man, of the vestiges of the left primitive vein ordinarily found in the adult human subject, and of the fresh example of double vena cava superior in Man met with by the author.

7. "A Mathematical Theory of Magnetism." By William Thomson, M.A., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow.

The theory of magnetism was first mathematically treated in a complete form by Poisson. Brief sketches of his theory, with some simplifications, have been given by Green and Murphy in their works on Electricity and Magnetism. In all these writings a hypothesis of two magnetic fluids has been adopted, and strictly adhered to throughout. No physical evidence can be adduced in support of such a hypothesis; but on the contrary, recent discoveries, especially in electro-magnetism, render it extremely improbable. Hence it is of importance that all reasoning with reference to magnetism should be conducted without assuming the existence of those hypothetical fluids.

The writer of the present paper endeavours to show that a complete mathematical theory of magnetism may be established upon the sole foundation of facts generally known, and Coulomb's special experimental researches. The positive parts of this theory agree with those of Poisson's mathematical theory, and consequently the elementary mathematical formulæ coincide with those which have been previously given by Poisson.

The paper at present laid before the Royal Society is restricted to the elements of the mathematical theory, exclusively of those parts in which the phenomena of magnetic induction are considered.

The author expresses his hope to lay before the Society a continuation, containing some original mathematical investigations on magnetic distributions, and a theory of induction, in ferromagnetic or diamagnetic substances.

8. "On the Nitroprussides, a new Class of Salts." By Dr. Lyon Playfair, F.R.S., F.C.S.

When nitric acid is made to act on yellow prusside of potassium, in the proportion of one equivalent of acid for every equivalent of potassium present in the salt, the following reactions are observed. The salt dissolves in the acid with a dark red, almost black colour, a very little nitric oxide is evolved, which soon ceases, and is followed by a copious evolution of cyanogen mixed with nitrogen. The continued action of the acid causes the liquid to cease the usual reactions of red prusside of potassium; the addition of sulphate of iron now produces a slate-coloured instead of blue precipitate. On allowing the solution to cool, abundance of nitrate of potash crystallizes out, mixed with a little prussian blue, and about 5 per cent. of the original weight of the salt, of a white granular substance, which is scarcely soluble in cold, and only very slightly so in boiling water. This white substance, on examination, proves to be the remarkable body *oxamide*, the production of which in an oxidising medium is highly singular.

The dark red supernatant liquor, being neutralized with an alkaline carbonate, and boiled, deposits a green precipitate and yields a clear ruby-red solution. This solution furnishes the new class of salts, which is the subject of this paper. It may be evaporated to crystallization, and yields the nitroprusside of the base used in the neutralization.

The characters of the nitroprussides thus obtained are very marked, and cannot be confounded with those of any known class of salts.

With soluble sulphurets, the nitroprussides produce the most magnificent purple-coloured solution, and of such intensity, that they form by far the best test for the presence of a sulphuret, and betray its presence when the usual tests for a sulphuret are insufficient to expose it.

With a protosulphate of iron, the nitroprussides produce a salmon-coloured precipitate; with salts of silver, zinc and cobalt, a precipitate of a flesh colour; and with nickel, a dirty white precipitate. With a salt of copper, the precipitate is of a light green, and with salts of lead, no precipitate is occasioned.

Nitroprussic acid is obtained by adding muriatic acid to the silver salt, and forms a dark red solution, which yields on evaporation *in vacuo*, large and well-defined crystals.

The nitroprussides of sodium, potassium, ammonium, barium and calcium, are all soluble and crystallize readily, forming fine large red crystals, which have been measured by Prof. Miller of Cambridge, and are described in the paper. The salts of barium and calcium decompose on evaporation, and can after that no longer be

obtained perfectly pure, having dissolved about one per cent. of the products of decomposition, which are not removed by subsequent crystallization.

Potash and soda in the cold unite with the nitroprussides, and form distinct salts, in which there is one equivalent of these alkalies for every equivalent of the baryle. These alkalies when heated with the nitroprussides decompose them altogether, forming peroxide of iron, hyponitrites, oxalic acid and ordinary ferrocyanides.

Sulphuretted hydrogen and soluble sulphurets also decompose the nitroprussides.

The formula of the nitroprussides is remarkably complex. Well-accordant analyses of all the salts permit no simpler relation between their carbon and iron than 24 equivs. of the former to 5 equivs. of the latter. The simpler proportion of 25 to 5 or 5 to 1, cannot be drawn legitimately from their composition. Analysis, and also a study of their transformation, show that they contain nitrous oxide, and have led to the complex formula

$$Fe_5Cy_{12}3NO+5R.$$

This is obviously a conjugate formula, and allows itself to be divided, for reasons now to be given, into the more simple expression

$$2(Fe_2Cy_3NO+2R)+(FeCy_2NO+R).$$

The relation of nitroprussides to ordinary prussides is supposed to be as follows:—

Both the ferrocyanides and the ferridcyanides are supposed to contain a common radical, one being quadribasic and the other tribasic, just as in the case of the modifications of phosphoric acid. A bibasic modification is therefore to be looked for. The formulæ would be as follows:

Ferrocyanides	$(Fe_2Cy_6)+4R.$
Ferridcyanides	$(Fe_2Cy_6)+3R.$
Hypothetical compound ..	$(Fe_2Cy_6)+2R.$

The nitroprussides are supposed to correspond to the last of the series, in which one equivalent of cyanogen is replaced by one equiv. of nitrous oxide. In the case of the beautiful purple compound produced by the soluble sulphurets on nitroprussides, this nitrous oxide is replaced by sulphuret of nitrogen. The hypothetical bibasic prusside necessary to establish this view has not yet been obtained; but the author states that experiments made with this view have already been so successful, that he shortly expects to announce it to the Society.

9. "On the Structure of the Dental Tissues of Marsupial Animals, and more especially of the Enamel." By John Tomes, Esq. Communicated by Dr. Grant, F.R.S.

The author of this communication, after examining microscopically the teeth of many marsupial animals taken from the majority of the families that make up the order Marsupialia, finds that they possess a structural character by which they may be distinguished from other

mammalian teeth, subject only to one of two exceptions; in which exceptions, however, the teeth are small and may readily be distinguished from marsupial by their external character. They are the teeth of the *Hyrax Capensis*, the British Shrews, and the molar teeth of the Jerboa.

The author states, that so far as he has had opportunities of examination, the teeth of the various species may also be distinguished, the one from the other. He points out, for instance, that, on comparison, the teeth of *Dasyurus ursinus* may be distinguished from the *D. macrourus*.

The peculiar characteristic of marsupial teeth exists in the continuation of the dentinal tubes into the enamel; so far as the author has investigated them, he finds but one exception, and that in the Wombat,—the representative of the rodents in the marsupial order. This creature, he finds, has teeth that are nearly allied in structure as well as external form to the teeth of rodents, and more especially to the Hare and Rabbit.

The author states, that he has observed that the dentinal tubes in the human and other teeth are sometimes continued for a short distance into the enamel. This he considers a rudimentary condition which is fully developed in the marsupial teeth. The author observes that the dentinal and enamel pulp become firmly united to each other previous to the commencement of calcification in either, and that it is highly probable that the linear columns of the two pulps are joined end to end, and that the columns of the enamel pulp so joined become developed into tubes instead of into solid enamel fibres. He considers this the more probable, as he has observed that the enamel fibres in an early stage of development are partially tubular in the teeth of several animals whose enamel fibres are ultimately solid.

The teeth described and figured are those of the—

Macropus giganteus.	Petaurus sciureus.
Hypsiprymnus penicillatus.	Dasyurus macrourus.
—— minor.	—— ursinus.
Phalangista vulpina.	Thylacinus cynocephalus.
Phascolomys Wombat.	Didelphis virginiana.
Petaurus taguanoides.	

The author considers that the facts stated in his paper justify two conclusions of a general character: first, that the existence of prolonged and fully-developed tubes in the enamel, continuous with those of the subjacent dentine, is common to the great majority, if not all, of the marsupial animals, excepting the Wombat; and, secondly, that the enamel and dentine are so closely related, that they should be regarded as modifications of each other, rather than as tissues of a wholly different nature.

10. "On the Motion of Gases."—Part II. By Thomas Graham, F.R.S. &c.

The experiments described by the author in the former paper on the

same subject, afforded grounds for assuming the existence of a relation in the transpirability of different gases, that is, their passage through capillary tubes, of an equally simple nature as that which is recognized among the specific gravities of gases, or even as the still more simple ratios of their combining volumes. Compared with solids and liquids, matter in the form of gas is susceptible of small variation in physical properties, and exhibits only a few grand features. These differences of property, which are preserved amidst the prevailing uniformity of gases, may well be supposed to be among the most deep-seated and fundamental in their nature with which matter is endowed. Under such impressions he has devoted an unusual amount of time and attention to the determination of this class of numerical constants. As the results, too, were entirely novel, and wholly unprovided for in the received view of the gaseous constitution, of which indeed they prove the incompleteness, it was the more necessary to verify every fact with the greatest care.

The most general and simple of the results is, that the transpiration velocity of hydrogen gas is exactly double that of nitrogen gas. These gases, it will be remembered, have a less simple relation in density, namely 1 to 14. This was the conclusion of his former paper respecting the transpiration of these gases, and he has obtained since much new evidence in its favour. The transpirability of carbonic oxide, like the specific gravity of that gas, appears also to be identical with that of nitrogen.

The result which may be placed next in point of accuracy and importance is, that the transpiration velocity of oxygen is related to that of nitrogen in the inverse ratio of the densities of these gases, that is, as 14 to 16. In equal times it is not equal volumes but equal weights of these two gases that are transpired, the more heavy gas being more slowly transpired in proportion to its greater density. Mixtures of oxygen and nitrogen have the mean velocity of these two gases, and hence the time of air is also found to be proportional to its density, when compared with the time of oxygen.

The relation between nitrogen and oxygen is equally precise as that between nitrogen and hydrogen. The densities calculated from the atomic weights of oxygen and nitrogen, namely, 16 and 14, being 1 for oxygen, 0·9010 for air and 0·8750 for nitrogen, the observed times of transpiration of equal volumes of the same gases are for oxygen 1, air 0·8970 to 0·9010, and for nitrogen 0·8708. The result for carbonic acid, which is perhaps next in interest, appears at first anomalous. It is, that the transpiration time of this gas is inversely proportional to its density when compared with oxygen, or 0·7272, the time of oxygen being 1, their velocities will of course be directly as their densities. It is to be remembered, however, that carbonic acid is a compound gas, containing an equal volume of oxygen. The second constituent, carbon, which increases the weight of the gas, appears to give additional velocity to the oxygen in the same manner and to the same extent as increased density from pressure or from cold increases the transpiration velocity of pure oxygen itself. A result of this kind shows at once the important chemical

bearing of gaseous transpirability, and claims for it a place with the doctrines of gaseous densities and combining volumes. The circumstance that the transpiration time of hydrogen is one-half of that of nitrogen, indicates that the relations of transpirability are even more simple in their expression than the relations of density among gases. In support of the same assertion may be adduced the additional fact, that binoxide of nitrogen, although differing in density, has the same transpiration time as nitrogen. Protoxide of nitrogen and carbonic acid have one transpiration time; so have nitrogen and carbonic oxide, as each pair has a common density.

The transpiration of twenty other gases and vapours is experimentally determined, and shown to be uniform, like the preceding gases, with tube resistances varying in amount from 1 to 1000. This list includes protocarburetted hydrogen, olefiant gas, ammonia, cyanogen, hydrocyanic acid, hydrosulphuric acid, bisulphide of carbon, sulphurous acid, sulphuric acid, chlorine, bromine, hydrochloric acid, ether, methylic ether, chloride of methyl, coal-gas and the vapours of water, alcohol and coal-tar naphtha.

The principal results respecting the transpiration of these vapours, and on the influence which pressure and temperature have upon the transpiration of a gas, are summed up as follows:—

The velocity of protocarburetted hydrogen is 0·8, that of hydrogen being 1.

The velocity of chlorine appears to be 1½ that of oxygen; of bromine vapour and sulphuric acid vapour the same as that of oxygen.

Ether vapour appears to have the same velocity as hydrogen gas; their densities are as 37 to 1.

Olefiant gas, ammonia and cyanogen appear to have equal or nearly equal velocities, which approach closely to double the velocity of oxygen.

Hydrosulphuric acid gas and bisulphide of carbon vapour appear to have equal or nearly equal velocities.

The compounds of methyl appear to have a less velocity than the corresponding compounds of ethyl, but to be connected by a certain constant relation.

The resistance of a capillary tube of uniform bore to the passage of any gas is directly proportional to the length of the tube.

The velocity of passage of equal volumes of air of the same temperature, but of different densities or elasticities, is directly proportional to the density. The denser the air, the more rapidly does it pass under a constant propulsive pressure.

Rarefaction by heat has a similar and precisely equal effect in diminishing the velocity of the transpiration of equal volumes of air, as the loss of density and elasticity by diminished pressure has.

A greater resistance in the capillary is required to bring out the law of densities, than appears necessary for the two preceding results; and a resistance still further increased, and the highest of all, to bring out the law of temperatures.

Finally, transpiration is generally promoted by density, and equally whether the increased density be due to compression, to cold, or to

the addition of an element in combination, as the velocity of oxygen is increased, by combining it with carbon without change of volume, in carbonic acid gas.

It did not enter into the plan of the author to investigate the passage of gases through tubes of great diameter, and to solve pneumatic problems of actual occurrence, such as those offered in the distribution of coal-gas by pipes. But he states that the results must be similar, with truly elastic gases such as air and carburetted hydrogen, whether the tubes be capillary or several inches in diameter, provided the length of the tube be not less than 4000 times its diameter, as in the long glass capillaries of his experiments. The small propulsive pressure applied to coal-gas is also favourable to transpiration, as well as the great length of the mains; and he therefore would expect the distribution of coal-gas in cities to exemplify approximately the laws of gaseous transpiration. The velocity of coal-gas should be 1·575, that of air being 1, under the same pressure. And with a constant propulsive pressure in the gasometer, the flow of gas should increase in volume with a rise of the barometer or with a fall in temperature, directly in proportion to the increase of its density from either of these causes.

These laws, it will be observed, are entirely different from those which direct the passage of gases through an aperture in a thin plate, or their flow into a vacuum as it is usually said, and could not be deduced, like the latter, from our speculative ideas respecting the elastic fluids.

11. "On the Automatic Registration of Magnetometers and Meteorological Instruments by Photography."—No. III. By Charles Brooke, M.B., F.R.S.

The author describes the construction of an apparatus for registering the variation of the thermometer and psychrometer on one sheet of paper. As in the apparatus for registering the vertical force magnetometer, described in a former paper, the photographic paper is placed between two concentric cylinders, placed with the axis vertical, and carried round on a revolving plate or turn-table by the hour-hand of a time-piece, which makes half a revolution in twenty-four hours; thus each half of the paper presents a record of the variation of one instrument during twenty-four hours. The scales of the instruments are continuously impressed on the paper by placing fine wires opposite each degree across the aperture through which the light falls on the stem; the light transmitted by the empty bore is intercepted by these wires, and the darkened portion of the paper is marked by a series of parallel pale lines corresponding to each degree: thus the distortion of the scale arising from the varying direction of the pencils of light is corrected. Every tenth degree is marked by a coarser wire, and therefore a broader line, as also the points 32°, 54°, 76°, 98°; one at least of these points will occur on each register, and the position of the extra broad line serves to identify the part of the scale to which the register relates.

An alteration in the mode of adjusting the wick of the camphine lamps described in a former paper is mentioned, by which the chance

of smoking is considerably diminished; likewise the successful application of naphthalized gas, and of an oil-lamp, to photographic registration.

The paper concludes with the description of a new method of determining the scale and temperature coefficients of the force magnetometers, by which a greater degree of accuracy is presumed to be attained than by the methods ordinarily employed. Two magnets, designed for self-registering instruments for the observatories at Cambridge and Toronto, having been submitted to this method, gave consistent results which indicate the law of the temperature coefficient to be sensibly different from that which has hitherto been assumed.

12. "On certain Properties of the Arithmetical Series whose ultimate differences are constant." By Sir Frederick Pollock, Lord Chief-Baron of the Exchequer, F.R.S. &c.

This paper professes to investigate certain properties of the series of whole numbers whose ultimate differences are constant, and incidentally to treat of Fermat's theorem of the polygonal numbers, and some other properties of numbers.

Its object is to show that the same (or an analogous) property which Fermat discovered in the polygonal numbers belongs to other series of the same order, also to all series of the first order, and probably to all series of all orders. It also proposes to prove the first case of Fermat's theorem (that is of the triangular numbers) from the second case of the squares (which had not before been done), and to dispense with the elaborate proof of Legendre (Théorie des Nombres), finally, to prove all the cases by a method different from that either of Lagrange, Euler, or Legendre.

It is first shown that an analogous property belongs to all series of the first order (viz. common arithmetical series). The following propositions are then proved as the basis of future reasoning:—

1. Every triangular number greater than 6 is composed of 3 triangular numbers.

2. Every triangular number greater than 3 is composed of 4 triangular numbers.

3. Any triangular number may be expressed by the form $(a^2 \pm a + b^2)$.

4. The sum of any two triangular numbers may be expressed by the same form.

5. Every number above 7 is the sum of *four* triangular numbers *exactly*.

6. Every number above 29 is the sum of *three* triangular numbers *exactly*.

7. Every multiple of 8 is composed of eight odd squares, and the sum of any 8 odd squares is a multiple of 8.

8. The following general theorem is then proved:—

If p be any odd square, then

$$Ap' + Bp'' + Cp''' + Dp'''' + \&c.$$

will equal 8 odd squares, if

$$A + B + C + D +, \&c.$$

equal 8, or any multiple of 8 (A, B, C, D, &c., z, y, x, &c, may be any positive whole numbers).

9. It is a corollary from this, that in any system of notation having an odd square for its base, the sum of the digits will have the same number of odd squares as the number itself; the number of odd squares being in each case the minimum.

10. Any number of the form $8n+4$ is composed of 4 odd squares.

11. It follows from this that every number is composed of 4 triangular numbers, or 3, 2 or 1.

12. From this it is shown that every number is of the form

$$(a^2 \pm a + b^2,\ c^2 \pm c + d^2).$$

13. And that every number of the form $4n+2$ (if n be greater than 2) is composed of 4 square numbers, 2 even and 2 odd.

14. And that every number greater than 27 is composed of 8 squares exactly.

15. Every number (beyond a certain small limit) is composed of 2 triangular numbers + a square number, or 2 triangular numbers + a double triangular number.

16. A proof is then offered that in the equation $8n+4=4$ odd squares, one of the four odd squares may be any odd square less than $8n+4$, and therefore 1 may be one of the 4 odd squares; and if so,

$$8n+4=1+3 \text{ odd squares},$$

$$\therefore 8n+3=3 \text{ odd squares},$$

from which Fermat's theorem of the triangular numbers is an immediate corollary.

17. A proof (by a tabular series) is then suggested, that all the other cases of Fermat's theorem may be deduced from the first, and that it is not necessary to use more than four terms greater than unity (as discovered by M. Cauchy, see Suppl. to Legendre's Théorie des Nombres, p. 21, 22).

18. A general expression for a succession of series is then given—

$$1, (p+1), (3p+1), (6p+1) \text{ &c.} \left(\frac{\overline{n-1}.n}{2}p+1\right);$$

and it is proved that any number may be composed of not exceeding $p+2$ terms of the series, of which three only are required to be greater than unity. If $p=9$, the series is 1, 10, 28, 55, &c., that is every third triangular number beginning with 1; and every number of the form $9n+q$ consists of q triangular numbers not divisible by 3 (if q be greater than 2).

If $p=8$, the series is 1, 9, 25, 49, &c.

19. (The odd squares) *and every number may be composed, of not exceeding* 10 *odd squares.* If $p=6$, the series becomes 1, 7, 19, 37 &c. (the differences between the cubes). From the continued addition of the terms of this series, the cube numbers may be formed.

If $p=4$, the series is 1, 5, 13, 25 &c., or

$$1, (1+4), (4+9), (9+16), \text{ &c.}$$

The continued addition of the terms of this series forms the octohedral numbers, viz. 1, 6, 19, 44, &c.

Every term of the series is composed of $(p+1)$ prior terms; also if q be added to any term it will equal $(q+1)$ prior terms.

20. It is then proved that the property of the triangular numbers is not destroyed by adding any (the same) number to each term, it is merely postponed, and commences at a higher number according to the magnitude of the number added.

21. The same is proved in respect of the addition of any common arithmetical series.

22. The paper concludes by suggesting a proof that every number may be composed of 4 triangular numbers, derived from the consideration that if the triangular numbers be indexed or numbered thus—

1	2	3	4	5 &c.	indices.
1	3	6	10	15 &c.	Δ^n nos.

Any number between 2 triangular numbers can be formed by 4 triangular numbers, the sum of whose indices shall be not less than the sum of the indices of the 4 triangular numbers that compose the smaller triangular number, and not greater than the similar indices of the larger; and generally (after a limited number of terms) the sum of the indices of any intermediate number will be exactly the sum of the indices of the smaller number: to illustrate this, all the numbers between 91 and 105 (2 triangular numbers) are shown to consist of 4 triangular numbers, whose indices exactly equal 25, which is the sum of the indices of the 4 triangular numbers into which 91 may be divided—

$$\text{thus } 91 = \overset{6}{21} + \overset{6}{21} + \overset{6}{21} + \overset{7}{28}$$

the sum of the indices $6+6+6+7=25$; and every number between 91 and 105 may be composed of 4 triangular numbers, whose indices added together will equal 25; but the nature of this investigation cannot be made intelligible without reference to the table itself, which the paper contains.

If this attempt is successful, the whole of Fermat's theorem of the polygonal numbers may be proved without reference to Lagrange's proof of the case of the squares (the second case) derived from the properties of the prime numbers. The writer intimates an intention of making further communications on the same subject.

13. "On the Analysis of Numerical Equations." By J. R. Young, Esq., Professor of Mathematics in Belfast College. Communicated by Sir John W. Lubbock, Bart., F.R.S. &c.

The object of this communication is to diminish the labour attendant upon existing methods for the analysis of numerical equations. As Budan pointed out intervals, within the bounds of the extreme limits of the roots of an equation, in which all search for roots would be fruitless, so here the author seeks for what he terms "*rejective intervals*" among those which Budan had retained. This he proposes effecting by transforming the first member of every equation $X=0$ into

$$X=\{F+\sqrt{F^2-X}\}\times\{F-\sqrt{F^2-X}\} \quad \ldots\ldots \quad (1.)$$

which the author calls decomposing it into *conjugate factors*; in

which factors, F is entirely arbitrary. On account of this unrestricted character of F, innumerable changes may be effected on a pair of conjugate factors, without disturbing their product: but it is from the following expression of these factors that the general results in this paper are chiefly deduced: namely,

$$\left.\begin{aligned} X=\{F+f+\sqrt{F^2+2Ff+f^2-X}\} \\ \times\{F+f-\sqrt{F^2+2Ff+f^2-X}\} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (2.)$$

from which it follows that, having decomposed any function X into a pair of conjugate factors (1.), we may always afterwards add any quantity, f, to the rational part of each factor; provided we, at the same time, introduce the expression $2Ff+f^2$ under the radical: and it is upon this general truth that the results in the paper entirely depend, and from which the *rejective intervals* are discovered.

The value of the principle is illustrated by examples taken from Sturm, Fourier, and others; and some general theorems are deduced—applicable to all equations—in reference to the existence of imaginary roots, which furnish some remarkably simple criteria. For instance: it is shown that if, in the general equation of the fourth degree,

$$x^4+ax^3+bx^2+cx+d=0,$$

in which d is positive, the condition

$$4(b-\tfrac{1}{4}a^2)d>c^2$$

exists, all the roots are necessarily imaginary. And that if, in the general equation of the sixth degree,

$$x^6+ax^5+bx^4+cx^3+dx^2+ex+f=0,$$

in which f is positive, the condition

$$4\{d(b-\tfrac{1}{4}a^2)-\tfrac{1}{4}c^2\}f>(b-\tfrac{1}{4}a^2)e^2$$

exists, each member being positive, all the roots are necessarily imaginary.

The paper concludes with some general propositions, derivable from the principles established in the preceding investigations, and which the author conceives to be of value in the analysis of equations.

14. "On some Phenomena and Motions of Metals under the influence of Magnetic Force." By William Sykes Ward, Esq. Communicated by William West, Esq., F.R.S.

In the course of some experiments relative to the principal phenomena of dia-magnetism, the author observed that the nature or direction of the action upon many metals varied with the intensity of the magnetic force, the effects being in accordance with the observations of Professor Plücker; and in pursuing his researches with the view to ascertain how far the magnetic and dia-magnetic forces might be coexistent in the same metal, other phenomena dependent on the power of the magnet presented themselves.

On submitting gold, silver, lead, tin, zinc and cadmium to the action of the electro-magnet when excited by an electric current of moderate strength, or when the polar terminations of the magnet

were at a distance not less than an inch, these metals pointed axially. When the battery power was somewhat increased and the poles brought nearer to each other, instead of the metal being more strongly attracted, it became less sensible to either attraction or repulsion, becoming very sluggish in its motions; but when the magnet was well-excited and the polar terminations brought within a quarter of an inch of each other, most of those metals pointed decidedly equatorially, and were repelled as dia-magnetics.

The author found that the phenomenon of revulsion, described by Faraday and more particularly noticed by him in copper, was exhibited in nearly all metals which are less magnetic than platinum, or less dia-magnetic than antimony, and noticed that the direction of the revulsive motion is different in magnetic and in dia-magnetic metals. He also noticed that in metals, whether pure or compound, which changed from the magnetic to the dia-magnetic state, the direction of the revulsion changed.

Experiments are next described which were instituted for the purpose of ascertaining the order in which different metals are affected magnetically or dia-magnetically.

Phenomena are also described which present themselves when the polar terminations are from 0·25 inch to 0·1 inch apart, and a disc of metal is so suspended that one-half of it is between and the other half beyond these terminations. If the metal be amongst those classed as magnetic, or be magnetically affected by the power employed, it is attracted, and after the first motion has subsided, clings to one of the polar pieces; if the metal be dia-magnetic, it is repelled and in many instances driven entirely out from between the poles. At the instant of the completion of the voltaic circuit, the disc of metal moves transversely, with a tendency to pass outwards from between the poles; and on breaking the circuit, the disc moves transversely in the contrary direction. The directions of these transverse motions are alike in all metals which do not become so strongly attracted by the magnetic influence as to cling firmly to one of the polar terminations, being in the same direction with platinum and palladium as with antimony and bismuth; but they are exhibited with greatest force by those metals which decidedly show revulsion.

The author makes various hypothetical assumptions in order to explain the phenomena he has described; and, in conclusion, states his opinion, "that the metals which have been observed to change from the magnetic to the dia-magnetic state are subject to three different conditions of molecular arrangement: the first, one of magnetic polarity, and which on its cessation only induces a feeble electric current; the second, the intermediate or sluggish state, in which the metal is not polarized so as to be either attracted or repelled by the magnet, but in which there is nevertheless so great a molecular disturbance that very powerful electric currents are induced on its discontinuance; and the third, in which the particles are so polarized as to be repelled by the poles of the magnet which has induced such condition, but which last condition does not, on its discontinuance, induce powerful electric currents."